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ARTERIOGRAPHIC DEMONSTRATION OF STATIONARY ARTERIAL WAVES

by

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It has occasionally been observed during arteriography that segments of apparently normal vessels change alternately in width in a characteristically regular manner so that appearances resembling a string of pearls are transiently produced (Figs 1 to 4). 'Stationary arterial waves' seems to be an appropriate and convenient term for the phenomenon and will be used in this communication. The term is a descriptive one and, it should be noted, does not refer to the permanent wave-like arterial outlines sometimes observed at the site of mural lesions, e. g. in sclerosis of the media.

As far as the author is aware these waves have apparently received little attention, and nothing seems to be known of their nature or possible diagnostic significance. Though the present investigation is incomplete and tentative it was thought that its publication might be of interest.

Material. Two hundred and seventeen consecutive arteriographies of the lower limb, performed in 160 patients in our department were reviewed. The age and sex distribution of the material is given in Diagram 1, and the arteriographic diagnoses are summarized in Diagram 2.

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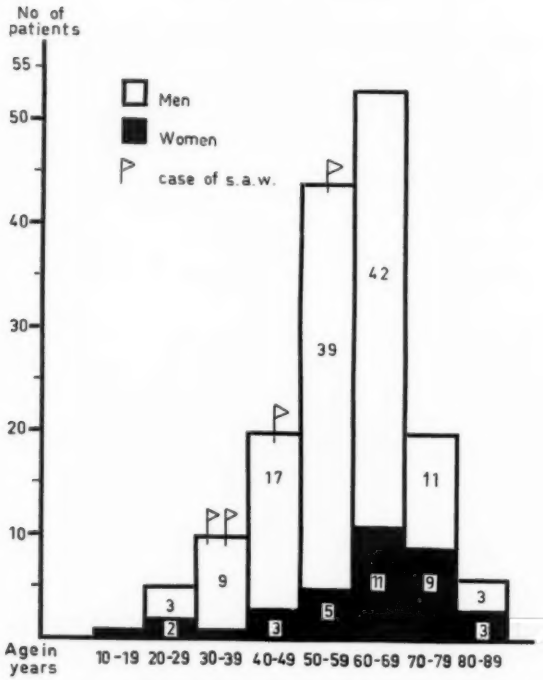


Diagram 1. Age and sex distribution of patients studied and occurrence of stationary arterial waves (s. a. w.).

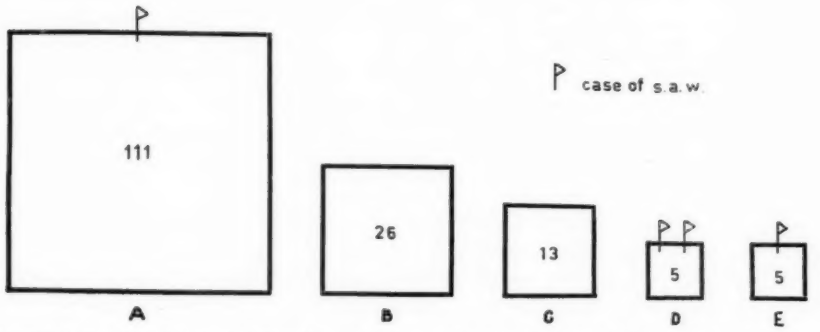


Diagram 2. Number of patients with: A) Arteriosclerosis or endarteritis, B) Normal arteries, C) Tumor, aneurysm or fistula, D) Embolism, E) Obscure lesions. Occurrence of stationary arterial waves (s. a. w.).

A standard technique was used in the examinations. The femoral artery was punctured under local anaesthesia or, exceptionally, under spinal anaesthesia or after sciatic block, and serial films were taken during and after the injection of 30 ml Urografin 60 % (Schering) with the needle directed cranially. In most cases the injection was repeated twice. Anticoagulants had been given prior to the examination in some cases, but no other drugs were used. The film-focus distance was 1.2 m throughout.

Results

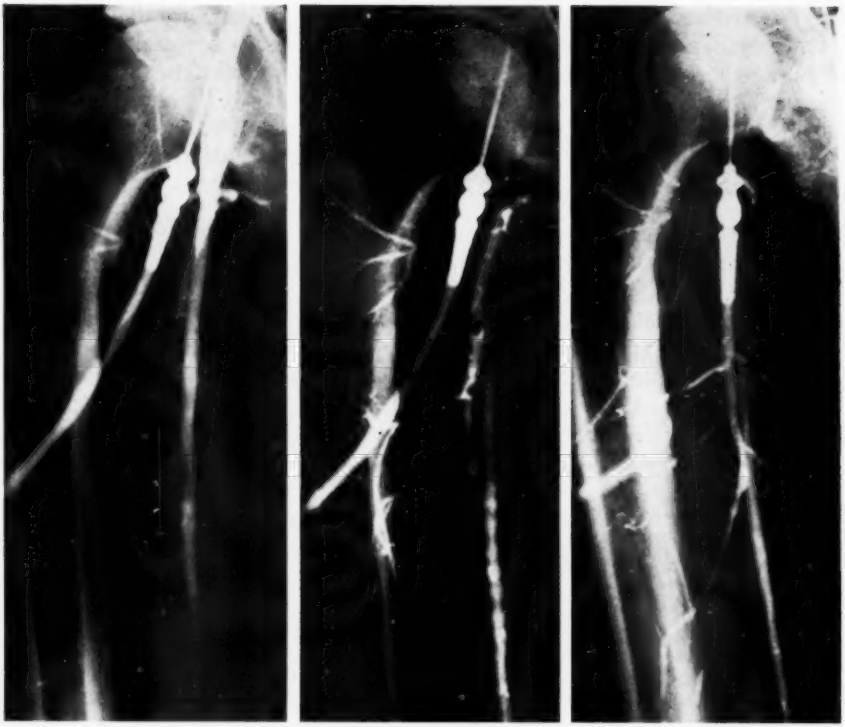
Stationary arterial waves were observed in 4 patients, all men, aged 32, 33, 41 and 52 years. Of these, 2 suffered from arterial embolism, 1 had clinical and arteriographic signs of thrombo-angiitis obliterans, and 1 had vascular lesions of obscure origin (Diagrams 1 and 2). It appears that, although rare, the phenomenon was overrepresented in patients under 60 years of age, and in arterial embolism.

Case 1. Male, aged 52, with a history of mitral stenosis, cardiac insufficiency and auricular fibrillation. Sudden pain in the abdomen and both legs suggested arterial embolism. Arteriography, performed under local anaesthesia within 6 hours of the onset of symptoms, revealed small emboli in the deep femoral and popliteal arteries of the right leg. No mural lesions were demonstrable, nor was any collateral circulation observed. Stationary waves appeared in the superficial femoral artery and in the proximal part of the deep femoral artery, i. e. above the most proximal embolus in both vessels. In the deep femoral artery the flow of contrast medium was initially obstructed by the proximal embolus (Fig. 1a); the waves were more prominent at this stage than when the contrast medium had overcome the obstruction (Fig. 1b). In the superficial femoral artery only part of the vessel was affected and proximal and distal to it the lumen was conspicuously narrower than at the crests of the waves.

The clinical signs of embolism disappeared in a few days. On control arteriography under local anaesthesia 3 weeks later no emboli or stationary waves were observed. The arteries were narrower than on the previous occasion (Fig. 1c).

Case 2. Male, aged 33, with a history of mitral stenosis, auricular fibrillation, and repeated arterial emboli in the legs and the cerebrum, for which he had been treated conservatively. Further emboli in the right leg with severe ischaemia, however, called for surgical intervention. Arteriography under spinal anaesthesia within 2 hours of the onset of the symptoms revealed emboli occluding the superficial femoral artery and some branches of the deep femoral artery (Fig. 2a). No stationary waves were observed on that occasion. The embolus at the origin of the superficial femoral artery was removed surgically, and the signs of ischaemia disappeared. A month later the mitral stenosis was treated by valvulotomy.

On control, arteriography under local anaesthesia 4 months after the embolectomy, the femoral artery and the superficial femoral artery presented normal appearances. Residues of emboli and post-embolic mural lesions were, however, demonstrable in the deep femoral artery and in some of its branches and arterioles. Only one such lesion appeared to obstruct the flow of contrast medium, and a few centimetres more proximally

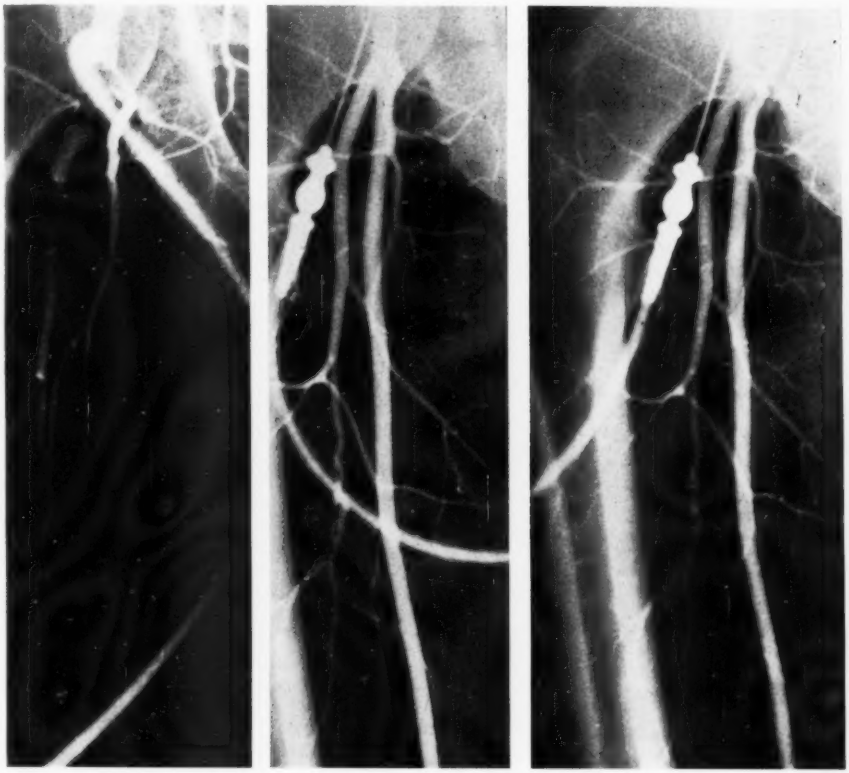


a b c

Fig. 1. Case 1. Embolism. a) and b) Acute stage. Standing waves in deep femoral artery proximal to emboli, most prominent in (a) where the flow of contrast medium is temporarily obstructed. b) Similar waves in part of the superficial femoral artery. c) Three weeks later: narrower arteries, no emboli or waves.

stationary waves occurred in a segment of the arterial branch from which the obstructed arteriole originated (Fig. 2b). Films obtained following a second injection of contrast medium a few minutes later failed to demonstrate any waves. On this occasion some of the contrast medium had passed beyond the site of previous occlusion by the time the exposures were made (Fig. 2c). In none of the arteriographic examinations was any collateral circulation demonstrable.

There were three further cases of arterial embolism in the material. Arteriography in these revealed recent emboli and a collateral circulation by-passing obstructions due to advanced arteriosclerosis or repeated embolism but no stationary waves.

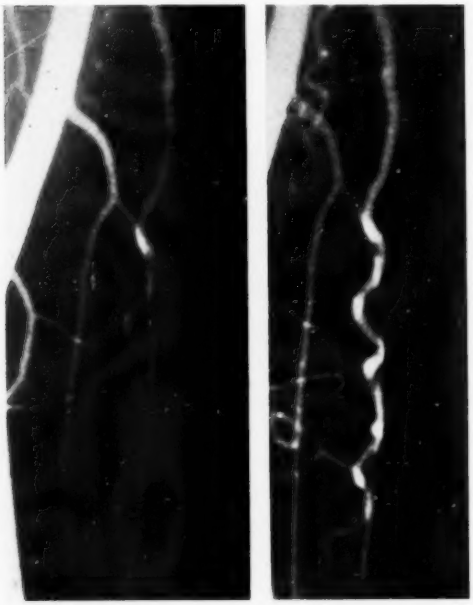


a b c

Fig. 2. Case 2. Embolism. a) Acute stage. Multiple recent emboli with occlusion of superficial femoral artery and branches of deep femoral artery. b) and c) Four months later. Residues of emboli and post-embolic lesions in deep femoral artery and one of its arterioles. Stationary waves proximally to the latter on temporary arrest of flow (b).

Case 3. Male, aged 32, with a history of venous thrombosis, crural ulcer, and intermittent claudication of the right leg. Thrombo-angiitis obliterans was suggested clinically, and arteriography under local anaesthesia revealed minute non-obstructive mural lesions in the superficial and deep femoral arteries which were compatible with this diagnosis. Two branches of the superficial femoral artery were conspicuously tortuous; in these the flow of contrast medium seemed to be retarded, and in one of them stationary waves proximal to the tortuosities were noted (Fig. 3).

In the remaining 110 cases of endarteritis or arteriosclerosis the mural lesions were definitely more advanced and as a rule obstructive, and a collateral circulation had been established.



a b

Fig. 3. Case 3. Thrombo-angiitis obliterans. a) and b) Slow flow through two tortuous arteries; stationary waves in one of these above the tortuosities.

Case 4. Male, aged 41, with a history of sudden and marked painless swelling of the soft tissues above and below the right knee without joint symptoms but with an elevated skin temperature of the affected area. Irregular periosteal thickening of the posterolateral region of part of the right tibial diaphysis was observed roentgenographically, and Sr^{85} was taken up at a significantly increased rate at the upper end of the right tibia. The clinical suggestion of neoplasm indicated arteriography, which was performed under local anaesthesia 17 days after the onset of symptoms. The arteries were of ordinary appearance, except that stationary waves occurred in two branches of the popliteal artery supplying the calf. The phenomenon was observed on three consecutive injections of contrast medium. No difference in the width of the vessel lumen or the size of the waves was observed on these occasions (Fig. 4).

Microscopic examination (LINELL) of a specimen taken from the right calf revealed an abundance of unevenly distributed vessels with abnormally thick and irregularly shaped walls. Their appearances and arrangement were suggestive of a vascular malformation, but the specimen did not permit of a definite diagnosis.

Arteriography under local anaesthesia about 2 years later revealed no stationary waves. The arteries still presented a normal gross appearance. After slow partial regression the swelling had increased again, and similar soft tissue changes had developed in other parts of the right leg. No definite diagnosis had been established.

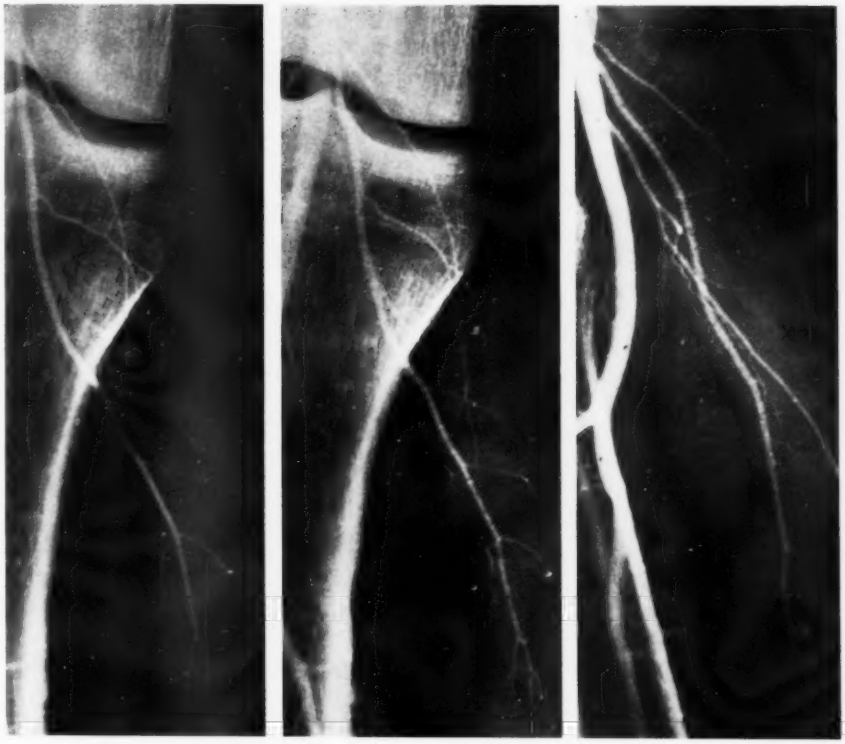


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Fig. 4. Case 4. Stationary waves in two popliteal branches supplying the right calf. Three consecutive injections of contrast medium.

To sum up, stationary arterial waves were rare in the present material. They were seen only in patients under 60. In 3 of the 4 cases observed, the phenomenon proved to be transitory. In all cases the waves were situated proximal to a vascular region in which arteriographic or microscopic examination revealed lesions capable of interfering with the flow of the blood and contrast medium. The phenomenon did not occur in extremities with many wide collaterals. In one case the vessel was obviously wider when stationary waves were noted than when they were absent.

The size of the stationary arterial waves apparently depended on the width of the vessel involved. In an attempt to find a numeric expression

for this relationship, measurements were made in the films to determine the diameter of the lumen at different levels, as well as the amplitude of the waves and their corresponding number per unit of length. The figures thus obtained are given in the table below. The values are probably not accurate, since it was not possible to correct for distortion due to the perspective. Nevertheless, they seem to reveal a tendency for the amplitude of the waves to be larger and of the number of waves per centimetre to be smaller the wider the vessel. The lumen was narrower at the troughs and, in 3 cases, wider at the crests than proximal to the waves.

Dimensions of vessels with stationary arterial waves: C — Calibre of lumen in mm, C_p — proximal to, C_c — at the crests of, and C_t — at the troughs of the waves, A — amplitude $C_c - C_t/_4$, N — number of waves/cm.

	C_p	C_c	C_t	A	N
Case 1	5.6	6.5	5.4	0.28	1.3
Case 2	2.3	2.5	2.1	0.1	4.0
Case 3	<2.5	2.5	1.9	0.15	4.9
Case 4	2.2	2.2	1.8	0.1	5.7
Case 4	1.6	1.5	1.2	0.08	7.7

Discussion

In a study of 'arterial spasm' WICKBOM & BARTLEY (1957) included an arteriogram in which stationary arterial waves were seen in the superficial femoral artery. The patient was a man, aged 32, with thromboangiitis obliterans. The phenomenon was absent in films obtained after further injection of contrast medium and after the administration of Priscol into the vessel, and was described by the authors as 'spasm'. Its appearance differed, however, from that of a typical local spasm as exemplified in illustrations by these authors and by LINDBOM (1957).

Observations made in the present material do not confirm the interpretation of stationary waves as a manifestation of spasm. On the contrary, the widening of vessel segments when the waves are present seems to be against this view. In a search for some other explanation of the phenomenon, consideration might be given as to whether it can be interpreted in purely physical terms.

A fluid when forced through a tube by pressure variations is subject to a longitudinal wave motion which will be reflected if the flow of the fluid is arrested. Any standing waves which thus develop behind the obstruction will be amplified if resonance occurs. If elastic, the tube may then be moulded by the nodes and antinodes and thereby acquire a shape similar to that of a string of pearls. Since these considerations probably hold for a limited part of the arterial system, with no or a few branches, it may be justified hypothetically to interpret the stationary arterial

waves as standing waves amplified by resonance. It appears that this conception would explain the hitherto known properties of arterial waves, e. g. their rarity and transiency, their relation to age and disease, their location proximal to vascular lesions, and their effect on the width of the lumen, as well as the relation of their size to the calibre of the vessel. Our present knowledge, limited as it is, thus seems to support the attempts to interpret stationary arterial waves as physical phenomena. Definitive conclusions must, however, await further observations.

SUMMARY

A rare but characteristic variation in the shape of arteries termed 'stationary arterial waves' is described. The possible explanation that these waves may be in the physical nature of amplified standing waves is put forward and discussed.

ZUSAMMENFASSUNG

Eine seltene aber charakteristische Variation der Arterienform genannt 'stationary arterial waves' wird beschrieben. Die Möglichkeit dass diese Wellen in ihrer physikalischen Natur verstärkte stehende Wellen sind, wird vorgeschlagen und diskutiert.

RÉSUMÉ

L'auteur décrit une variation rare mais caractéristique de la forme des artères appelée 'ondes stationnaires artérielles'. Comme explication possible il avance et discute l'hypothèse qu'elles pourraient être de la nature physique d'ondes permanentes amplifiées.

REFERENCES

LINDBOM, Å.: Arterial spasm caused by puncture and catheterization. Acta radiol. 47 (1957), 449.

WICKBOM, I. and BARTLEY, O.: Arterial 'spasm' in peripheral arteriography using the catheter method. Acta radiol. 47 (1957), 433.

FROM THE ROENTGEN DEPARTMENT (DIRECTOR: ÁKOS KOVÁCS), SEMMELWEIS HOSPITAL, BUDAPEST, HUNGARY

ASYMMETRIC ROENTGENOGRAPHY OF THE VOCAL CHORDS

by

Ákos Kovács

The problem of making the roentgenologic examination of the larynx a satisfactory complement to laryngoscopy has for long received attention and the rendering of good detail has constituted the primary aim of those interested in this region.

The true vocal chords are more or less visible in ordinary anteroposterior roentgenograms of the larynx, in which they are projected symmetrically. With the techniques of SMERCHINICH and HUET, SURMONT & LALANNE the lateral films which are required can be obtained only if the patient has a long neck and the larynx is mobile. Tomography (GUNSETT, GREINEDER, PAGANI, GAY, ERDÉLYI, ZSEBÖK) produces a symmetric projection of the vocal chords but is not entirely satisfactory as the movements of the tube and film necessarily result in blurring of detail. RÉTHI's method cannot be employed without anaesthesia of the pharyngeal and laryngeal mucosa before the film is introduced into the hypopharynx.

The method now described reproduces the right and left vocal chords separately and asymmetrically and with sharp outlines. The views obtained are comparable and the examination forms a good routine diagnostic procedure.

The vocal chords when at rest converge as they run from behind forwards but on phonation come to lie parallel to each other in the sagittal

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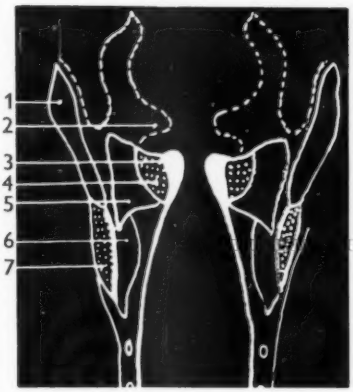


Fig. 1. Anatomy of the larynx. 1 — Cartilago thyr. 2 — Plica ventricul. 3 — Plica vocalis. 4 — Musc. vocalis. 5 — Cartilago aryt. 6 — Cartilago cricoid. 5 — Musc. cricothyroid.

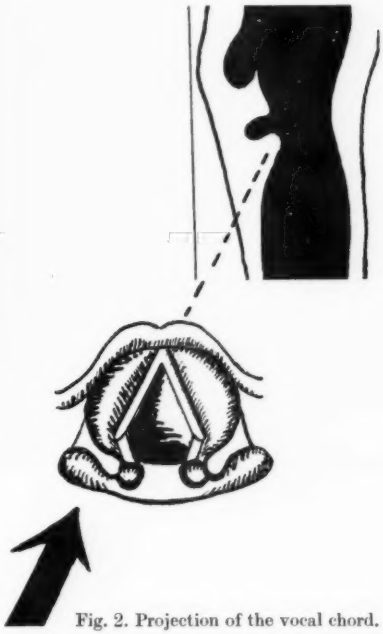


Fig. 2. Projection of the vocal chord.

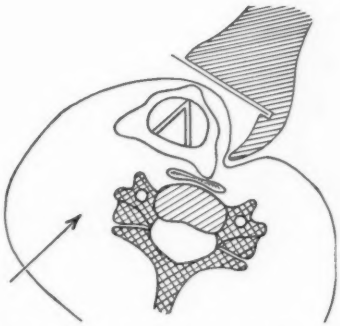


Fig. 3. Device for displacing the larynx.

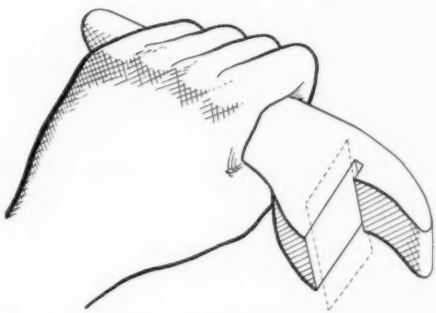


Fig. 4. Position of film and displacer of the larynx.

Fig. 5 Fig. 6

Fig. 5. Cadaver. Collapsed vocal chords with narrowing of the saccule of the larynx.

Fig. 6. Vocal chords in a male aged 20.

plane. If therefore a vocal chord is to be shown in its full depth, an asymmetric oblique projection must be used (LINDGREN). The demonstration of the vocal chords is based on the fact that they are situated in a contrasting medium, i. e. the air column in the larynx (Fig. 1). The vocal chord to be examined should be positioned so that the central ray strikes it as it lies outlined by air (Figs 1 and 2). This however is not the only consideration and care must be taken that the vertebral column is avoided so that the soft parts are not masked by bone.

The necessary positioning is performed as follows:

1. With the patient sitting the head is rotated away from the side to be examined; the slight torsion produced upon the larynx brings the vocal chord of this side into approximately the frontal plane and out of the way of the spine.

2. A special combined film holder and instrument for displacing the larynx is now employed (Figs 3 and 4). The device is manipulated by the patient. The patient takes a deep breath, lets it out, and holds it in expiration, this having the effect of moving the larynx upwards. He then presses the device into the soft parts of the neck and the exposure is made. The central ray is directed from behind at an angle of between 30° and 40° with the sagittal plane.

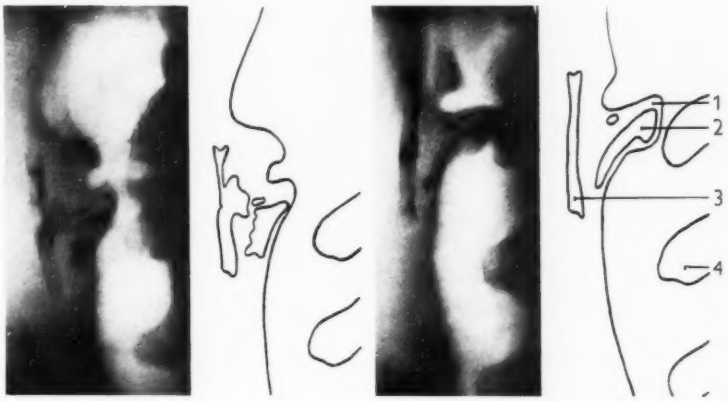


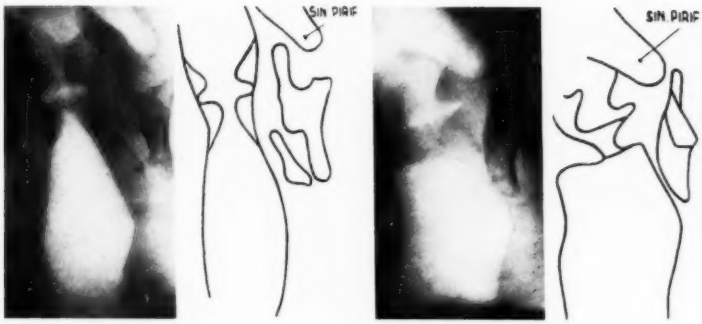
Fig. 7. Male aged 26. Films of function, with breathing through the nose (a), and under phonation, the plica vocalis in the phonatory position (b).
1 — Plica voc. 2 — Cart. aryt. 3 — Cart. thyr. 4 — Proc. transv.

The procedure is then repeated for the opposite side, the two sides being exposed on one 9 × 12 cm film. The magnification technique with a fine focus tube may also be employed, in which case the larynx is displaced by means of pressure applied by a non-opaque instrument.

Fig. 8. Female, aged 26. Phonatory position. Early ossification in arytenoid cartilages.

Fig. 9. Female, aged 23. Films of function, with breathing through the nose (a), and in the phonatory position (b).

Fig. 8 Fig. 9a Fig. 9b



a b

Fig. 10. Female aged 30. Films of function, with breathing through the nose (a), and during the Valsalva manoeuvre (b).

Results

The thickness of the true vocal chords and the degree of development of the false chords can be established by this method. The depth of the sinus or ventricle of the larynx can be estimated and the position of the arytenoid cartilages can be ascertained. Ossification in these cartilages commences at about the age of 26 in men and around 23 in women and is generally complete in old age.

The movements of the arytenoid cartilages and vocal chords are well shown (Figs 7 and 8). The contraction of the piriform fossa on phonation can be demonstrated. This phenomenon is probably due to the action of the thyreopharyngeal muscles. When the Valsalva maneouvre is performed both the subglottis and piriform fossa dilate (Fig. 10).

The method described has the advantage that it permits the demonstration of the vocal chords in their physiologically normal position at rest, with the patient breathing through the nose, and the mouth closed. There is no interference with the innervation of the pharynx, which may occur when the tongue is drawn forwards and the pharynx distended in laryngoscopy.

This communication is concerned with the method per se. Two cases in which it was employed may however be mentioned. In one a lentil-sized polyp seated on a vocal chord was revealed by the method, as well as by laryngoscopy. After operation both examinations showed that the vocal chord was normal. In the other case a tumour was demonstrated on the inferior surface of a vocal chord giving rise to contraction of the subglottis.

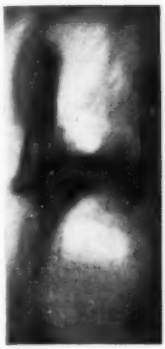


Fig. 11a

Fig. 11a

Fig. 11b

Fig. 11b

Fig. 12

Fig. 11. Male, aged 66. Polypus, before operation (a), and same case after operation (b).

Fig. 12. Tumour of the vocal chord in a male aged 56.

Conclusion

The method appears to constitute a reliable diagnostic procedure and a satisfactory complement to laryngoscopy. It is particularly valuable for demonstrating proliferation below the vocal chords since their inferior aspects are usually beyond the range of the laryngoscope. It is also useful for the documentation of the pre-operative appearances, for examinations of function, and for control purposes during deep therapy.

SUMMARY

A method of asymmetric roentgenography of the vocal chords is described.

ZUSAMMENFASSUNG

Eine Methode asymmetrischer Röntgendarstellung der Stimmbänder wird beschrieben.

RÉSUMÉ

L'auteur décrit une méthode de radiographie asymétrique des cordes vocales.

REFERENCES

1. ERDÉLYI, M.: Die Schnittuntersuchung des Larynx. Mag. Röntg. Közl. 17 (1943), 44.
2. GAY, BRIT. B.: A roentgenologic method for evaluation of the larynx and pharynx. Amer. J. Roentgenol. 79 (1958), 301.
3. GUNSETT, A.: Über die Anwendungsmöglichkeit der Planigraphie bei Erkrankungen des Kehlkopfsinneres, insbesondere beim Carzinom des Endolarynx. Fortschr. Röntgenstr. 56 (1937), 705.
4. HUET, P. C., SURMONT, J. et LALANNE, C. M.: La radiographie du larynx en translation. Sem. Hôp. Paris 31 (1955), 601.
5. LEGLER, U. und SCHLUNGBAUM, W.: Röntgendarstellung des Larynxinneren in der Frontalebene bei seitlicher Verschiebung (Lateroposition) des Kehlkopfes. Röntgenblätter 7 (1954), 337.
6. LINDGREN, E.: Über die Röntgenuntersuchung des Larynx. Fortschr. Röntgenstr. 59 (1939), 273.
7. MCINNES, J.: Radiography of the larynx. X-Ray Fokus 1—21 (1956).
8. POWERS, E. W., MCGEE, H., and SEMAN, B. W.: Contrast examination of the larynx and pharynx. Radiology 68 (1957), 169.
9. RÉTHI, A.: Die Röntgenuntersuchung des Kehlkopfes und der Luftröhre. Dtsch. med. Wschr. 38 (1937), 1912.
10. SMERCHINICH: Sagittalaufnahme des Kehlkopfes. Röntgenpraxis 13 (1941), 277.
11. SICHEL, D., WILD, I. P. et VOEGTLIN, W.: Intérêt de la tomographie du temporal dans les otorrhées chroniques. J. Radiol. Électrol. 36 (1955), 461.
12. WILD, CH., SICHEL, D. et HEIMENDIGER, E.: Valeur respective des radiographies du larynx de face après déplacement latéral et des tomographies du larynx. Ann. Oto-laryng. 73 (1956), 262.
13. ZSEBÖK, Z.: Das Schnittbild des Larynx. Radiol. clin. 21 (1952), 307.

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THE TECHNICAL PROCEDURE IN KIDNEY EXAMINATIONS WITH RADIOACTIVE ISOTOPES

by

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The first reports on the use of radioactive isotopes in the evaluation of renal function were published in 1956, when TAPLIN and his collaborators described experiments in animals and in a few clinical cases. They used 131 iodine-marked Diodrast and Urokon as contrast media, the excretion of which may be followed from without by means of a scintillation counter. TAPLIN et coll. reported that radioactive Urokon does not seem suitable for clinical use, as patients with known unilateral renal diseases had to be examined for several hours before any difference could be observed in the excretion values on the two sides. Radioactive Diodrast, on the other hand, proved to be well suited for clinical work as the characteristic features of the excretion curve were observable within 10 minutes after the intravenous injection. We have used a similar method in 24 cases in our department. There are no contra-indications other than those current for the intravenous use of iodized contrast media. The excretion may be followed by different methods. The total number of impulses in the scintillation counter during a given time may, for instance, be counted at regular intervals, but more exact results will be obtained by continuous recording of the number of impulses in the counter (registration with an Easterline-Angus recorder). Furthermore, when a rate meter is available, the impulse rate at each moment of time

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may also be continuously recorded. Only the first two methods were used in our cases. The radioactivity in the blood rises to a high level immediately after the injection and then decreases, while at the same time there is a rapid increase in the radioactivity in the kidneys. In proportion as the amount of radioactive contrast medium conveyed to the kidneys gradually falls below the amount excreted, the renal uptake decreases. TAPLIN measured the radioactivity of the blood by making determinations in blood samples taken at given intervals. A simpler procedure is to make a direct determination with a scintillation counter directed towards some part of the body sufficiently far away from the kidneys to be out of reach of disturbing impulses from these organs. In our investigations, a scintillation counter with a large aperture was focussed on the patient's head.

The technical significance of the size of the aperture and its influence on the appearance of the curves does not seem to have been previously treated in the literature. The larger the aperture, the smaller is the amount of radioactive material that can be injected at the examination but the greater will be the amount of radiation influencing the scintillation counter from areas outside the kidneys. This is of particular significance in examinations of the right kidney, as about 10 % of a radioactive iodopyracet preparation is excreted through the liver. TAPLIN et coll. did not mention the size of their aperture; probably, however, it was fairly large, since they reached the conclusion that the measurements should be carried out in a vertical direction with the patient sitting and bent forwards so that the influence from the liver activity would be as slight as possible. The dose of radioactive Diodrast used, about 30 microcuries, was also relatively low. DENNEBERG & HEDENSKOG did not obtain usable results with radioactive Diodrast owing to influence from the radioactivity in the liver region, and employed in its place 131 iodine-marked Hypaque which does not give any demonstrable uptake in the liver.

We have not obtained sufficient exactitude in centering when using TAPLIN's technique with the patient sitting and bending forwards. A decrease in the size of the aperture will reduce the area from which the radiation influences the scintillation counter; the amount of radioactive contrast medium necessary to give an effect strong enough for correct recordings must, however, then be increased. Furthermore, the smaller the aperture, the more important is it to focus accurately on the kidneys and to have as equal conditions as possible on both sides. We find that an aperture of 12.5 mm with a length of 5 cm seems suitable for practical purposes. With this size, however, the dose of 131 iodine-marked iodopyracet solution must be higher than that used by TAPLIN et coll.; at least 50 microcuries should be employed. The kidneys always

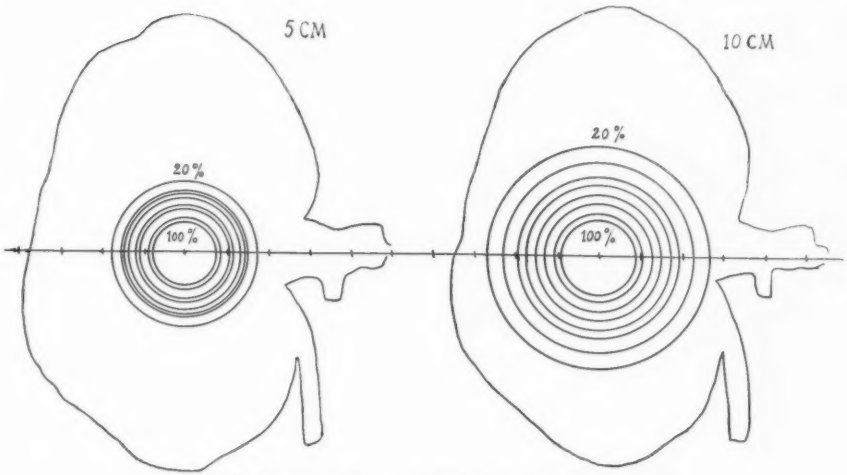

Fig. 1. Isogons with an aperture diameter of 12.5 cm.

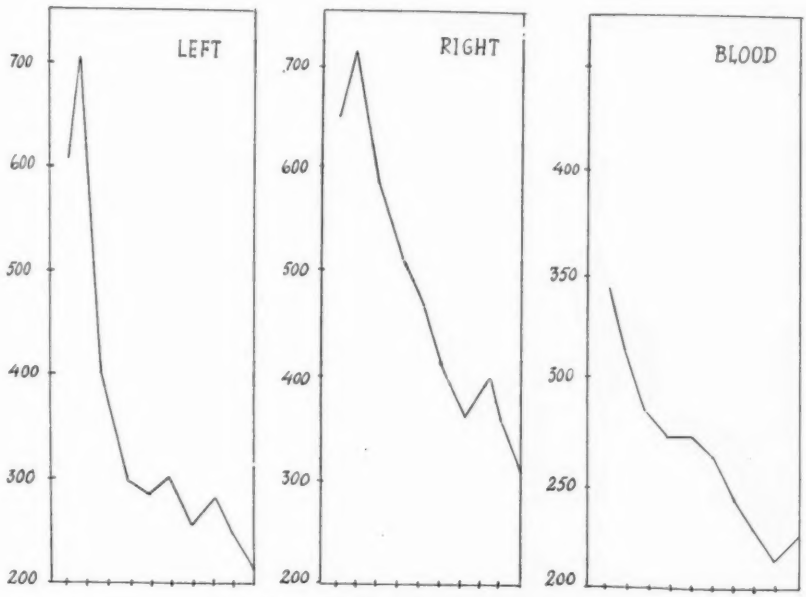

Fig. 2. Normal excretion curves.

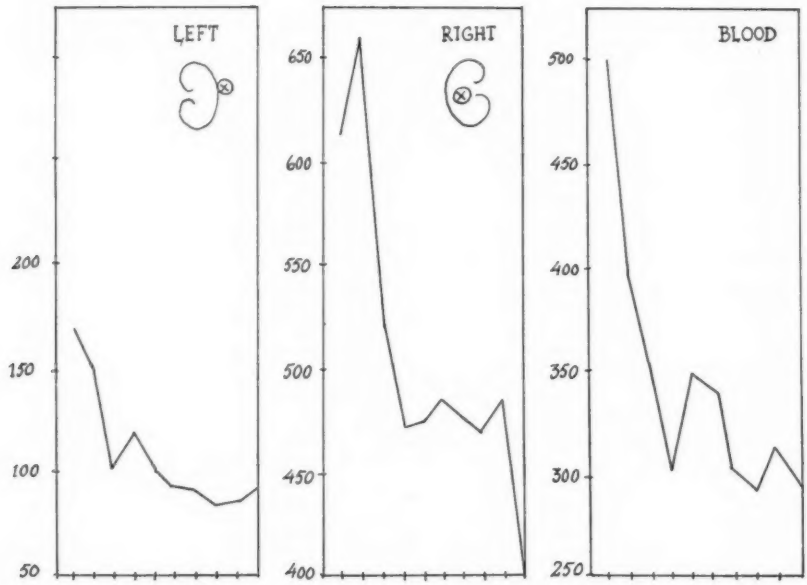

Fig. 3. Normal case. The cross indicates the position of the aperture in relation to the kidney.

lie at a given distance from the aperture and the area from which the radiation is measured will thus be larger than that corresponding to the size of the aperture. The kidneys vary moreover in depth in different subjects. The conversion of the radiation into impulses will be greatest in the centre of the area and gradually diminish towards the periphery. The isogons of the aperture determine the size of the area to be measured. (An isogon is the line which, at a given distance from the aperture, binds together the points in the measurement area from which the same part of the radiation intensity is converted into impulses in the scintillation counter.) If the aperture is circular, the isogon will also be circular. When projected over the kidney, the isogons of the aperture used in our examinations appear as in Fig. 1. With an aperture diameter of 12.5 mm the diameter of the centre area will be 15.5 mm at a distance of 5 cm, and 18 mm at a distance of 10 cm.

In order to ascertain how the measurement results were influenced by the focussing of the aperture we used the following technique. Under fluoroscopic control, the middle of each kidney was marked on the patient's back and roentgen films were then taken over each kidney

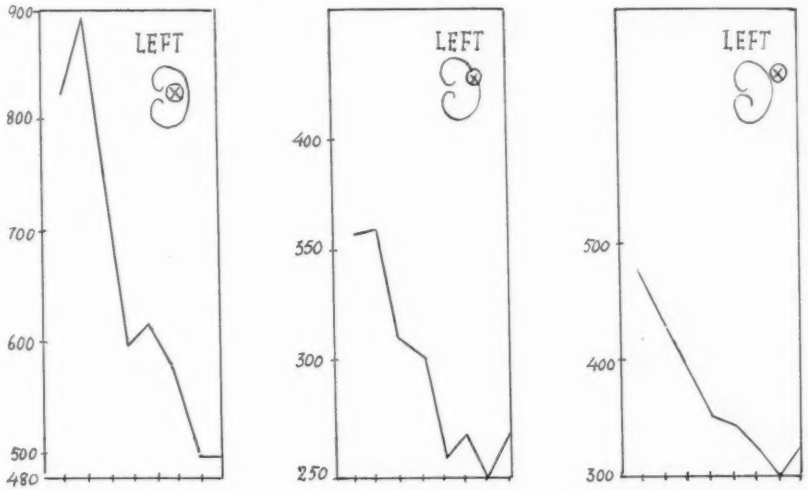

Fig. 4. The appearance of the excretion curves with varying position of the aperture on the left side.

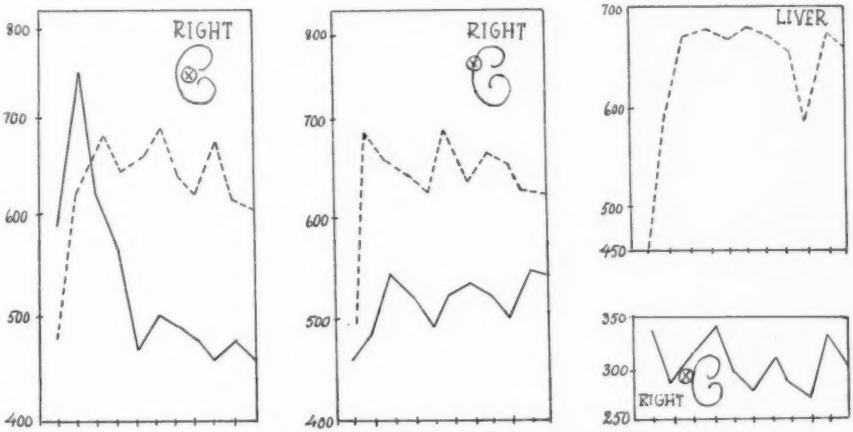

Fig. 5. A similar experiment to the one in fig. 4 but on the right side. The dotted line represents the radiation from the liver.

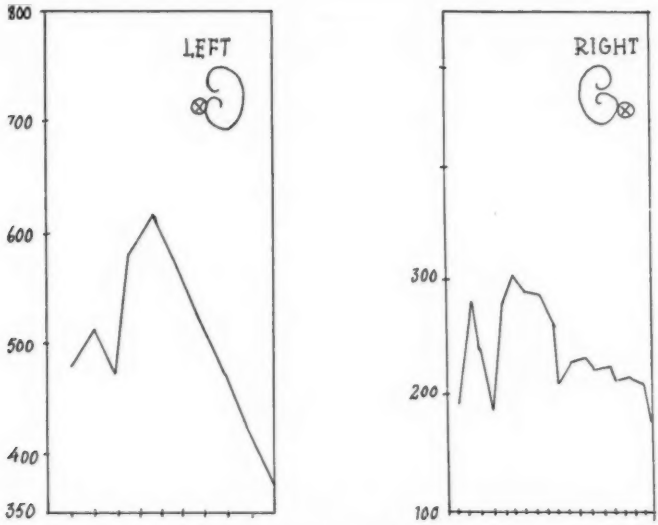

Fig. 6. The appearance of the excretion curves when the aperture is situated medially to the kidney.

with a lead indicator applied to the spot on which the aperture of the scintillation counter was focussed. The measurements were carried out in a horizontal direction. A normal curve obtained when the aperture was directed towards the middle of the kidneys is seen in Fig. 2, which demonstrates that with the aperture and technique used, the curves will be practically the same on the right and left sides and hence that the measurements on the right side are not influenced to any degree by radioactivity from the liver. If, on the other hand, the left scintillation counter was placed immediately lateral to the left kidney, the curves shown in Fig. 3 were obtained; from the left side, a curve closely resembling that of the blood was obtained. The charging phase of the kidney curve was entirely absent. In Fig. 4, curves from an experiment in which the aperture was gradually moved from the centre of the left kidney to a point at 5 mm distance from the kidney are given. When the aperture was focussed on the lateral margin of the kidney a deformed curve was obtained in which only suggestions of radioactive uptake in the kidney could be observed; from the area immediately outside the kidney, a blood curve was obtained. Fig. 5 shows the results from a similar experiment on the right side; here the curves were influenced by the liver activity, and hence by the size of this organ and the position of the kidneys in

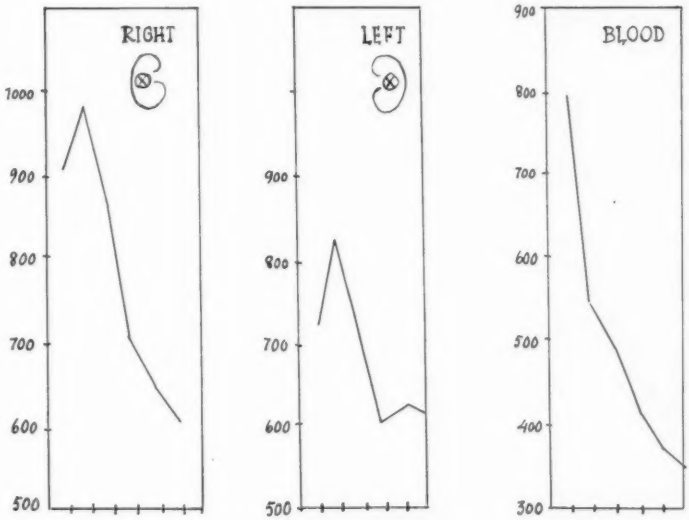

Fig. 7. Normal curves in the case of chronic nephritis.

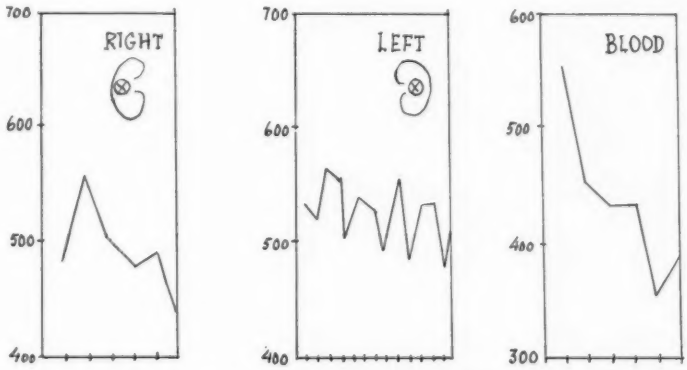

Fig. 8. Normal curve on the right side. Case of left-sided pyelonephritis.

relation to it. By way of comparison, the radiation from the liver was also determined by focussing the aperture on the liver at the greatest possible distance from the kidneys.

When the centering was medial to the kidneys, the curves varied in appearance according to the concentration of radioactive medium in the renal pelvis, in the large renal blood vessels and, on the right side, in the liver. Small alterations in a craniocaudal direction, with the aperture centered immediately medial to the kidneys, also gave curves of entirely different appearances. When the aperture was centered medial to the upper pole of the left kidney a blood curve was obtained, and when the centering lay medial to the same part of the right kidney the curve was influenced markedly by the excretion through the liver. If the aperture was centered immediately medial to the middle and lower parts of the kidney, the curves shown in Fig. 6 were usually obtained. The curves have two peaks, the second being the higher in time. The first peak is probably due to the charging of the kidney and the second to radiation from the radioactive medium being excreted in the renal pelvis and ureter.

We doubt whether radioactive isotopes will have any particular future clinical significance in examinations of the kidneys, as in the majority of cases the method gives no information additional to that obtainable by other means. It is, however, of some value in cases in which unsatisfactory contrast density in the renal pelvis has been obtained at urography and when there is some uncertainty as to whether this is due to pathologic changes and reduced renal function, or to an ineffective examination technique. A case of chronic nephritis was examined by ordinary urography, and only poor excretion was obtained on both sides although the specific gravity of the urine varied between 1.009 and 1.022 on repeated tests. In view of this discrepancy, an isotope examination was carried out and normal function curves obtained (Fig. 7). This occasioned renewed urography which produced normal findings. Hence the result of the first examination was probably due to technical errors. In another case, in which the contrast density in the renal pelvis was much less on one side than on the other, examination with a tracer gave the curves in Fig. 8. The result of the urographic investigation was thus due to the presence of a pathologic process in the kidney and not to faulty technique; chronic pyelonephritis was established at operation.

SUMMARY

The technique of renal examinations with radioactive iodopyracet is described with reference to a material of twenty-four cases. Scintillation counter methods were employed and emphasis is laid upon the size of the aperture and accurate centering. The clinical value of the isotope examination in selected cases is discussed.

ZUSAMMENFASSUNG

Die Technik der Nierenuntersuchung mit radioaktiven Jodopyracenen wird an Hand eines Materials von 24 Fällen beschrieben. Scintillographische Zählmethoden wurden verwendet. Besondere Sorgfalt wurde auf die Spaltgrösse und Genauigkeit der Zentrierung gelegt. Der klinische Wert der Isotopenuntersuchung von ausgewählten Fällen wird diskutiert.

RÉSUMÉ

L'auteur décrit la technique de l'examen rénal par les iodopyracéts radioactifs, en se basant sur une série de vingt-quatre cas. Il a utilisé les méthodes de compteur à scintillation et insiste sur l'importance des dimensions de l'ouverture et du centrage précis du compteur. Il étudie l'intérêt clinique de cet examen isotopique dans des cas sélectionnés.

REFERENCES

Denneberg, T. and Hedenskog, I.: Erfarenheter av nefrogram med radioaktivt Hypaque. (In Swedish.) Nord. Med. 21 (1959), 812.

Taplin, O. O., Meredith, O. M., Kade, H. and Winter, C. C.: The radioisotope renogram. J. Lab. clin. Med. 48 (1956), 866.

Winter, C. C.: A clinical study of a new renal function test: The radioactive Diodrast renogram. J. Urol. 76 (1956), 182.

Editor's note:

Names for new medical procedures seem often to be selected without due regard for linguistic or semantic considerations. Furthermore, the possibility that the term chosen may be confused with others already in current usage for other techniques or methods is ignored. The designation first introduced has a tendency to survive, even if later on its inadequacy may be realized. In the roentgenologic literature words ending with the suffix -gram signify records of images obtained essentially by roentgenographic procedures: cystogram, urogram, pyelogram, kymogram, etc, and they are accepted in this sense in the general medical language. At the same time words with the ending -gram may also stand for reproductions of curves, or charts of statistical data, or for records or tracings of phenomena, although then mostly with the addition of an attribute to differentiate them from those signifying roentgen procedures; electrocardiogram and electrokymogram are examples.

The term 'nephrogram' has so far been used to denote a roentgen representation of the kidney with the parenchyma rendered opaque by contrast medium, for instance in urography or renal angiography. Its use for the graphically recorded excretion of an isotope through the kidney — as has been evident lately in the literature — appears unfortunate and likely to lead to misunderstanding. This also applies to the word 'renogram' which has been used in a similar sense. 'Nephrogram' and 'renogram' may easily be confused with one another, and both may furthermore be confused with roentgenograms. These terms will not be employed in Acta Radiologica to indicate the excretion curve of an isotope through the kidney. And to ensure that their inappropriate use will not be perpetuated, it seems to us that it would be advantageous if our standpoint were generally accepted.

FROM THE ROENTGEN DEPARTMENT (DIRECTOR: S. RIBBING), CENTRALLASARETTET, LINKÖPING, SWEDEN

MENISCOGRAPHY BY VAN DE BERG'S DOUBLE CONTRAST TECHNIQUE

by

Ulf Zakrisson

Arthrography of the knee was introduced at the beginning of the century by WERNDORFF & ROBINSOHN, HOFFA, and WOLLENBERG. A number of techniques employing contrast media or gas have since been described. BIRCHER in 1931 introduced a double contrast technique.

The method most commonly used in Sweden was described by LINDBLOM and has constituted an important advance. In 1951 VAN DE BERG of Liège published a double contrast technique which was adopted by us and subsequently somewhat modified. It is intended solely for diagnosing lesions of the menisci, and renders possible detailed examination of the structures. Cases, in which other injuries such as tears of the cruciate ligaments are indicated, are outside the scope of this report.

Technique

The joint is aspirated from the medial approach and as much fluid as possible is drawn off. Eight to ten ml Umbradil (Astra) and 20 to 25 ml air are injected. In adults Umbradil 50 % is used, unless the joint is particularly small, and in younger subjects Umbradil 35 %. The 50 % preparation is also indicated in all cases when some fluid is thought to have been left in the joint. Passive and, particularly, active movements

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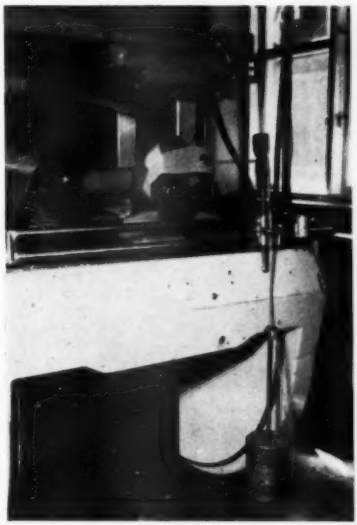

Fig. 1. Foot sheath with weight and pulley. Position of pulley at foot end of table can be adjusted vertically and horizontally. Position as for exposure 4 of the right medial meniscus.

Fig. 2. Knee sheath fixed to one side of the table. Position as for exposure 2 of the right medial meniscus.

of the joint are then carried out for a few minutes in order to produce a fine frothy mixture of contrast medium, air, and joint fluid; the patient is also instructed to walk, using the leg under examination as normally as possible. It is most important for the patient to perform these active movements, and we do not therefore as a rule examine a knee joint while the pain is acute. It is also preferable to delay investigation in the presence of a large effusion, when the capsule is lax, and in cases

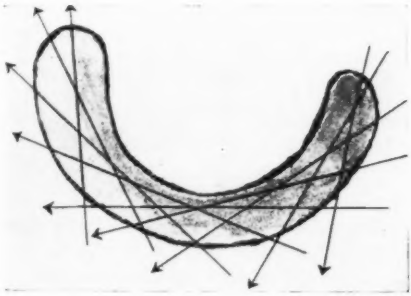

Fig. 3. Diagram of projections.

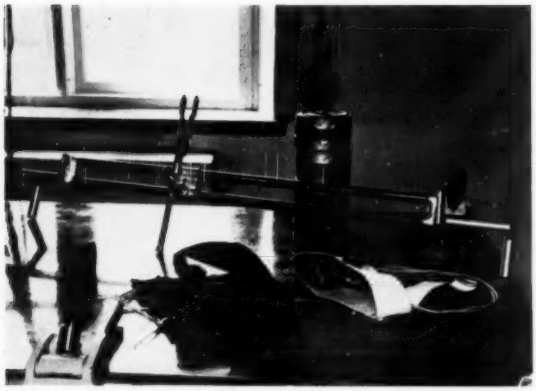

Fig. 4. Equipment for the examination.

of recent haemarthrosis. The contrast medium is absorbed fairly rapidly in young subjects, and the best results are obtained if the exposure can be made within 20 minutes. This is usually not difficult to achieve, and when only one cartilage is involved the examination can easily be completed within 15 minutes.

We have employed a Philips Symmetrix examination table, equipped with a double-focus tube (microfocus 0.3 × 0.3 mm). For a medium-sized knee-joint the exposure factors are: 96 kV, 80 mA, 0.6 sec, FFD about 105 cm, OFD about 50 cm. The primary grid is adjusted to give a frame size of about 6 × 5 cm. Six serial views are obtained on a 24 × 30 cm film, and 4 on an 18 × 24 cm film. Philips spot-film device greatly facilitates rapid and precise roentgenography, and allows final adjustment of the position of the joint under fluoroscopy before each exposure.

The patient lies prone on the table. The shoed foot is enclosed in a canvas sheath to which a wire is attached. This passes over a pulley at the upper end of a metal shaft, the other end of which is fixed to the lower end of the table where it can be adjusted both horizontally and vertically. The wire is weighted up to 15 kg (Fig. 1). The knee is enclosed in a cloth sheath which is fixed to one side of the table. By lateral adjustment of the pulley, slight varus or valgus flexion of the knee is obtained, the knee sheath providing countertraction. The object is to widen the joint space on the side of the meniscus to be examined. By raising or lowering the pulley the surface of the tibial condyle is brought into line with the beam. It is best to raise slightly the foot end of the table to prevent the patient from sliding down and to allow any surplus contrast

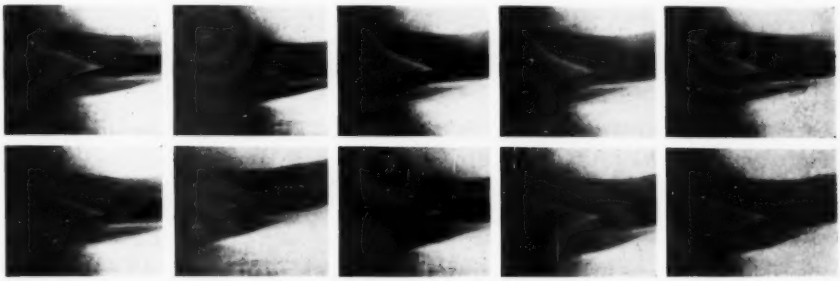

Fig. 5. Series of photographs of normal medial meniscus.

Fig. 6. Medial menisci. In left series normal structures, in right injured menisci.

Fig. 7. Lateral menisci. In left series normal structures, in right injured menisci.

medium to collect in the suprapatellar bursa and not to mask the menisci (Fig. 2).

The menisci are examined separately. Ten tangential projections are obtained under fluoroscopic control during continuous rotation of the joint. We always start at the front, that is, in the case of the medial meniscus with the limb in extreme internal rotation and, in the case of the lateral meniscus, extreme external rotation. The limb is rotated successively throughout the examination, the final exposure of the series showing the most posterior part of the border of the cartilage (Fig. 3). As a rule only one meniscus is investigated. If it is desired to examine the other, the knee sheath is fixed to the opposite side of the table to bring about countertraction, and the exposures are made immediately without repeating the injection of contrast medium.

Due to the fine focus of the roentgen tube it is possible to obtain direct enlargement up to × 2 with satisfactory clarity. This is achieved by increasing the object-film distance to about 50 cm. Owing to the considerable distance between the object and film, a secondary grid can be dispensed with (LAURELL).

After the examination the patient should rest the leg for a few days. The discomfort is not greater than that of other forms of arthrography, and no complications have occurred in our series of 280 investigations.

The reliability of the method may be judged on the basis of the 199 examinations carried out with this technique by the author personally. The series is not selected in any other way. The age distribution and incidence of medial and lateral meniscus injuries do not differ from those usually encountered. In order to assess the value of enlargement, a comparison is made of films taken before we introduced this improvement and those obtained more recently, the technique being otherwise unchanged.

Table

Knee injuries with pre-operative diagnosis of torn menisci and, respectively, normal menisci

	Number of cases		Treated by surgery		Roentgen diagnosis confirmed at operation		Wrong diagnosis	
	Torn	Normal	Torn	Normal	Torn	Normal	Torn	Normal
Arthrography without direct enlargement	18	24	16	4	15	2	1	2**
Arthrography with direct enlargement	83	74	68	12	66	9	2*	3**

* In one of these cases degeneration of the meniscus was found at operation, the cartilage being puckered at the site of the tear.

** In one case the lesion was easily detected on re-scrutinity of the films.

The most stringent test of the value of the method is of course the subsequent history of patients with a roentgen diagnosis of normal menisci. Of the 82 patients not treated by surgery (see the Table) 34 were instructed to return if the symptoms recurred; none has done so. This and the agreement of the roentgen and operative findings (see Table) suggests that the method should provide a reliable diagnostic aid. The diagnosis of meniscus lesions is elusive and requires practice. Our experience is that arthrography should be repeated in patients suspected clinically of having a meniscus injury but in whom the initial roentgen examination has failed to reveal a lesion.

SUMMARY

Arthrography of the knee joint by a modified VAN DE BERG's method is described. This was employed in a material of 100 cases with good agreement between the roentgen and operative findings. The value of the direct enlargement of films with the fine focus tube technique is discussed.

ZUSAMMENFASSUNG

Arthrographie des Kniegelenks mittels einer modifizierten VAN DE BERG's Methode wird beschrieben. Sie wurde an einem Material von 100 Fällen durchgeführt, wobei die röntgenologischen und die operativen Befunde gut übereinstimmten. Der Wert der direkten Vergrösserung der Filme mit der Feinfokusröhren-Technik wird besprochen.

RÉSUMÉ

L'auteur décrit une modification de la méthode de VAN DE BERG pour l'arthrographie du genou. Elle a été utilisée sur une série de 100 cas, donnant une bonne concordance entre les signes radiologiques et les constatations opératoires. L'auteur examine l'intérêt de l'agrandissement direct avec un tube à foyer fin.

REFERENCES

ANDERSEN, K.: Some experiences with a new method for arthrography. Acta radiol. 25 (1944), 33.

BIRCHER, E.: Pneumoradiographie des Knies und der anderen Gelenke. Schweiz. med. Wschr. 61 (1931), 1210.

— und OBERHOLZER, J.: Die Kniegelenkkapsel im Pneumoradiographie-Bilde. Acta radiol. 15 (1934), 452.

BRODIN, H. och RIBBING, S.: Meniskografi a. m. van de Berg. (In Swedish.) Nord. Med. 58 (1957), 1166.

HOFFA, A.: Über Röntgenbilder nach Einblasung von Sauerstoff in das Kniegelenk. Berl. klin. Wschr. 43 (1906), 940.

LAURELL, H.: Metallfolien und Metalltücher als Sekundärblenden. Uppsala Läk. Fören. Förh. 37 (1932), 440.

Lindblom, K.: Roentgenographic symptoms of meniscal lesion in the knee joint. Acta radiol. 21 (1940), 274.
Oberholzer, J.: Die Technik der Pneumoradiographie des Kniegelenkes nach Bircher. Zbl. Chir. 60 (1933), 1522.
— Die Arthro-Pneumoradiographie. Beitr. klin. Chir. 158 (1933), 113.
— Röntgendiagnostik der Gelenke mittels Doppelkontrastmethode. Thieme, Leipzig 1938.
Schaer, H.: Der Meniskusschaden. Thieme, Leipzig 1938.
Van de Berg, F. et Crèvecoeur, M.: La méniscographie en série du genou. Acta orthop. belg. 7 (1953), 293.
Zakrisson, U.: Meniskografi med dubbelkontrast a. m. van de Berg. (In Swedish.) Nord. Med. 61 (1959), 636.

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COMPRESSION OF THE COMMON ILIAC VESSELS BY DILATATION OF THE BLADDER

Report of a case

by

Erik Carlsson and *Per Garsten*

Compression of iliac vessels by a distended urinary bladder has not to our knowledge been described in the literature. This communication deals with such a phenomenon in a three weeks old male infant, in which the distention of the bladder was due to obstruction of its outlet by posterior urethral valves. The circulatory disturbance involved the left lower extremity. Surgical removal of the urethral obstruction resulted in a return of the circulation to normal.

Case report. A boy, aged 3 weeks, had been healthy for the first two weeks of life. The mother had observed that the abdomen was increasing in size, and the increase continued during the following week. There were no difficulties with micturition or defecation. When the child was 19 days old, the mother detected a right inguinal hernia not present earlier; at the same time, the left leg suddenly became cold, pale and cyanotic. The boy did not appear to be in pain but the coldness and discoloration increased and after six hours he was admitted to hospital.

Upon examination the child was found to be afebrile and in good general condition. The abdomen was enlarged and venous markings were prominent in the left lower quadrant. A hard fixed, somewhat lobulated mass with rounded edges was palpated in the lower

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a

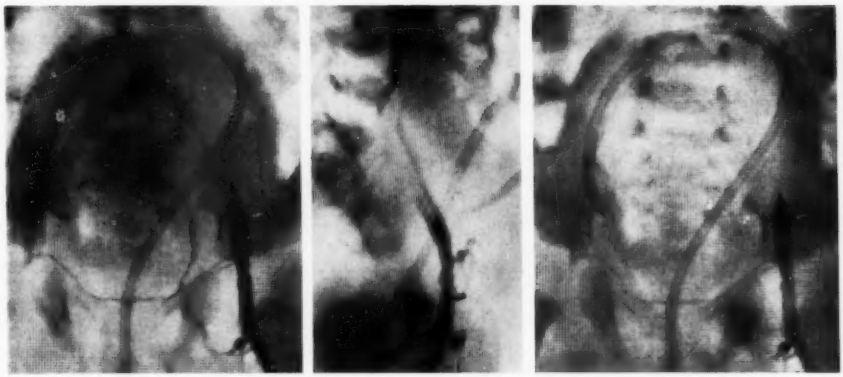
b

c

Fig. 1.

a) A. p. and b) lateral views obtained at urethrocystography before operation. Marked dilatation and trabeculation of the bladder; several diverticula present. The trigone is wide and the bladder neck bulges forwards in its dorsal segment. The urethra is widened down to cusp-like valves below the colliculus. The dorsal wall of the bladder reaches almost to the sacrum. No reflux filling of the ureters.

c) One month after operation. Valves not visible, the bladder neck is widened, and the trabeculation has diminished.



a b c

Fig. 2. Venography of left femoral and iliac veins after filling of the bladder with 100 ml saline. a) A. p. and b) lateral: Obstruction of the external and common iliac veins. The right femoral vein is filled via collaterals below the site of the left iliac obstruction. No obstruction on the right side. c) Contrast medium still visible 8 sec after the end of injection in the left femoral vein.

abdomen, rising to a point midway between the symphysis pubis and umbilicus; it was dull to percussion. Rectal examination: N. A. D. The left lower extremity was pale and cold; there was no venous engorgement, but the foot was cyanotic. No arterial pulsations could be palpated in either the groin or leg. The right lower extremity was normal.

After some difficulty, a urethral catheter was passed into the bladder and 120 ml of clear urine withdrawn. Following this procedure the abdominal mass was no longer present and there was definite improvement in the circulation of the left lower extremity which, however, remained cold and cyanotic.

Urography disclosed dilatation of the renal pelves and ureters. The urinary bladder was markedly dilated, trabeculated, and there was evidence of multiple diverticula. On micturition urethrocystography valves were demonstrated in the posterior part of the urethra (Fig. 1, a and b).

Transurethral electrosection of the bladder neck and urethral valves was performed along with perineal urethrotomy. The bladder was found to be markedly trabeculated. The urethral openings could not be seen. The posterior wall of the bladder neck bulged forwards and the proximal urethra was elongated and widened. The verumontanum was of normal length but was broad. Folds with characteristic cusp-like valves arose from the lower end of the colliculus. The left cusp and one of these folds were resected down to the level of the urogenital diaphragm; the fold seemed to be continuous with the cusp-like valve. *Microscopic examination* (IVEMARK): The tissue was fibrotic, vascularized, and covered with transitional epithelium which was mostly avulsed. The connective tissue was edematous. A number of islands of epithelium mostly of the transitional cell type were evident and in some places there were epithelial-lined cavities probably representing glandular tissue. No striated muscle was seen but a few streaks of smooth muscle were present.

Following the operation, circulation in the left lower extremity steadily improved. At the end of five days, the leg was warm and of normal colour but the toes remained cold. Two weeks after the intervention the circulation in the left lower extremity was entirely normal.

One month after treatment, *urography* and *urethrocystography* were performed. The dilatation of the renal pelves, ureters, and bladder had diminished considerably. Trabeculation of the bladder persisted but there was no reflux filling of the ureters. There was no urethral obstruction (Fig. 1c).

Discussion

Obstruction of the iliac veins has been described in cases with retroperitoneal abscesses (GRUNWALDT and TOMSOVIC 1957). There were no signs of an inflammatory condition in our case. The patient had no fever and the motility of the leg was normal.

In order to elucidate its mechanism, an effort was made to recreate the circulatory disturbance present on admission. The urinary bladder was filled with 90 ml saline following which it could be palpated midway between the symphysis and umbilicus. At the same time the left lower extremity became cyanotic; after emptying of the bladder, this feature disappeared.

Femoral venography was performed with both an empty and distended bladder. One hundred millilitres saline were instilled into the urinary bladder and 6 ml Urografin 50 % were injected into the left femoral vein. The contrast medium moved slowly and was visible in the femoral vein peripherally to the external iliac obstruction 8 seconds after termination of the injection. Contrast medium was also observed to pass by way of collaterals into the right femoral vein (Fig. 2).

After emptying of the bladder, a further femoral injection was followed by the rapid passage of contrast medium through the external iliac vein, with only slight narrowing at the site of the previous obstruction (Fig. 3).

Bladder dilatation and increased bladder pressure are often found in cases with urethral valves, but the complication of vascular obstruction is very rare. It is therefore reasonable to assume that special anatomical and/or functional conditions were present in our case which permitted the bladder to press upon the vessels. Close proximity of the vessels to the bladder evidently played a significant role, although the exact relationship could not be established.

SUMMARY

A case of obstructing posterior urethral valves and secondary compression of the iliac vessels by the distended bladder is described. Reproduction of the clinical picture by bladder distention and demonstration of the iliac vessel compression by venography, both before and after correction of the urethral obstruction, demonstrated the mechanism of the compression.

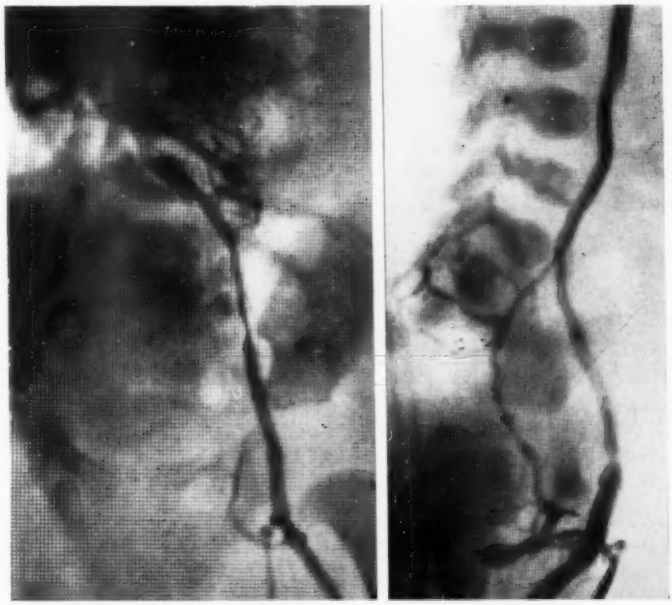


Fig. 3. Venography of left femoral and iliac veins without filling of the bladder. No obstruction. Slight narrowing of the external and common iliac veins which could be explained by layering of the contrast medium in the blood stream. No compression applied to the vena cava.

ZUSAMMENFASSUNG

Ein Fall von obstruierendem hinterem Uretersegel mit sekundärer Kompression der Iliakalgefässe, als Folge einer prall gespannten Urinblase, wird beschrieben. Die Reproduktion des klinischen Bildes durch Extension der Blase und venographische Darstellung der Kompression der Iliakalgefässe, sowohl vor als auch nach Korrektion der urethralen Obstruktion, konnte den Mechanismus der Kompression demonstrieren.

RÉSUMÉ

L'auteur décrit un cas de valvules uréthrales postérieures obstructives avec compression secondaire des vaisseaux iliaques par la vessie distendue. La reproduction des signes cliniques par la distension vésicale et la mise en évidence de la compression des vaisseaux iliaques par phlébographie faite avant et après correction de l'obstruction uréthrale prouvent le mécanisme de cette compression.

REFERENCE

GRUNWALDT, E. and TOMSOVIC, E. J.: Iliac vein obstruction caused by retroperitoneal abscess in newborn infants. J. Pediat. 50 (1957), 361.

FROM THE UNIVERSITY INSTITUTE FOR EXPERIMENTAL RESEARCH (DIRECTOR: PROF. CARL SEMB) AND THE ROENTGEN DEPARTMENT (DIRECTOR: PROF. FRIMANN-DAHL), OSLO, NORWAY

DEVELOPMENT OF MESENTERIC-PARIETAL COLLATERALS AFTER TRANSPOSITION OF SMALL BOWEL SEGMENTS IN RATS

by

Roar Funder and *Ragnar Hol*

The purpose of the investigation was to determine the viability and absorbtive properties of isolated loops of small intestine implanted subcutaneously in the abdominal wall of adult rats. Relatively good preservation of the mucosal function would be an indication that the segments were suitable for further transplantation. Similar studies have been made in dogs by MILLER, GROSSI, and LEWIN who aimed at replacing resected bowel by a transplanted loop of intestine. NEUMANN et coll. used a pedicled flap of intestinal mucosa for the absorption af ascitic fluid in dogs, a method which was later employed in human subjects by NEUMANN, ADIE, and HINTON as well as by BRUUSGAARD and FUNDER. Functioning intestinal mucosa has been transplanted far away from the abdominal cavity by NEUMANN, HOEN, and DAVIS, as well as by FERRER who used a segment of ileum as an absorbing pouch in congenital communicating hydrocephalus.

Method

Rats were employed as the experimental media. The abdominal cavity was opened under ether-alcohol anaesthesia and a 6 cm long segment of the small bowel was embedded in the abdominal wall, the mesenteric blood

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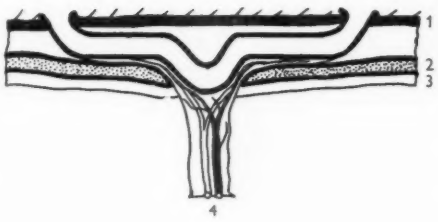

Fig. 1. Transposition of small bowel segment to the abdominal wall. The gut lies largely in the subcutis. 1 — Skin; 2 — Muscle; 3 — Peritoneum; 4 — Mesenterial pedicle with vessels.

supply being left intact; slight abrasions of the serous membrane were made before the embedding. The ends of the segment were sutured to small skin openings to allow for inspection and for the necessary function tests (Fig. 1), the small bowel being joined up again by end-to-end anastomosis.

Operative lieno-portal venography was performed 5 to 8 weeks after the transposition of the segment and a few animals were also examined in this way prior to operation. A fine polythene catheter (P. E. 10) was introduced into the splenic tissue by means of a metal guide and 0.8 ml Hypaque 45 % slowly injected; injection time 6 to 8 seconds. The first film was obtained 3 sec before the end of the injection and two more at about 3 sec intervals. During the injection a gauze pad, held by artery forceps, was pressed against the portal vein just below the hilum of the liver. By this means we attempted to reverse the blood stream in the superior mesenteric vein so that the contrast medium would flow retrogradely into it from the splenic vein and splenoportal junction. Exposure factors: 48 kV, 3 mAs, 0.003 sec, FFD = 100 cm; no grid. The exposure time should be very short as these animals have a rapid respiratory and cardiac action.

Results

A group of 6 of the operated rats were examined by lieno-portal venography. Contrast medium was evident in the spleen as well as in the splenic and portal veins in the preoperative films in some of these. No filling of the superior mesenteric vein occurred in spite of the portal compression. The proximal end of the superior mesenteric vein at the splenoportal junction appeared as a small bud (Fig. 2). Five to eight weeks after the small bowel transplantation we succeeded in reversing the blood flow in the superior mesenteric vein in 3 of the animals by portal compression during lieno-portal venography. Well developed mesenteric-parietal collaterals were evident (Fig. 3) and even the draining vessels to the axilla and the groin were well delineated in the films. A second injection of contrast medium about ten minutes later produced still better filling, probably due to vasodilatation.

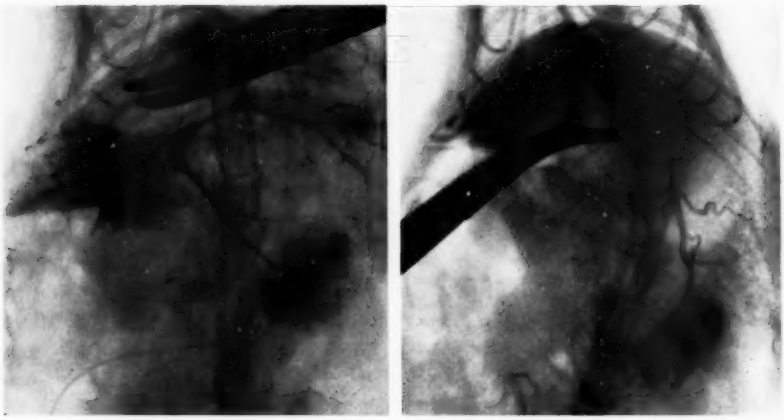

Fig. 2. Operative lieno-portal venography in a rat. a) Compression pad placed proximally to the liver. Good filling of the splenic vein and the portal vein and its branches to both liver lobes. The catheter for injection of contrast medium is seen across the lower abdomen. b) Compression pad in correct position. Contrast filling of the splenic vein and the distal part of the portal vein. The end of the superior mesenteric vein at the splenoportal junction appears as a small bud.

Of the remaining 3 animals in which no reversal of the blood stream could be produced, collaterals were visible in two at surgical opening. Furthermore, subsequent cutting off of the blood supply to the segments by ligation was well tolerated in all animals of the group.

Discussion

A large number of collaterals may develop between the portal and venacaval systems in portal hypertension (BERGSTRAND and EKMAN, DOEHNER et coll.) and the preformed small vessels connecting the two venous systems may become very large. Apart from the efficient methods of making porto-renal or porto-caval shunts, there have been reported attempts to encourage new collaterals by omentopexy (TALMA), by the production of adhesions between the liver and the diaphragm (MADDEN et coll.) and by the transposition of the spleen to the lower part of the left thoracic cavity (NYLANDER and TURUNEN). It may be that the beneficial effects of ileo-entectropy in cases of ascites reported by NEUMANN et coll. were due to the ingrowth of mesenteric-parietal collaterals.

We have demonstrated in our present experiments the establishment of well developed collaterals between the mesenteric and parietal veins in animals with an otherwise normal portal circulation. The rapid in-

Fig. 3. Operative lieno-portal venography six weeks after small bowel transposition. The blood flow in the superior mesenteric vein is reversed by the portal compression. a) Collaterals (arrows) draining both to the axilla and to the groin. b) The transposed small bowel segment is filled with medium via the skin openings. The technique otherwise as in the other cases. The segment is surrounded by collaterals (arrow).

growth of venous collaterals points towards the possibility of establishing a new venous pathway by small bowel transplantation. We have also found that it is possible to perform lieno-portal venography in small animals such as rats.

SUMMARY

Well developed collaterals between the mesenteric and parietal veins were demonstrated in 6 rats by lieno-portal venography five to eight weeks after the transposition of small bowel segments to the abdominal wall. The significance of the results is considered.

ZUSAMMENFASSUNG

Sechs Ratten wurden mittels Lienoportographie, 5 bis 8 Wochen nach der Verpflanzung von Dünndarmabschnitten an die Bauchwand, untersucht. Dabei konnten gut ausgebildete Kollateralen zwischen den Mesenterial- und Bauchwandvenen gezeigt werden. Auf die Wichtigkeit der Ergebnisse wird hingewiesen.

RÉSUMÉ

La phlébographie spléno-portale a mis en évidence, sur 6 rats, des collatérales bien développées entre les veines mésentériques et les veines pariétales, de cinq à huit semaines après la transposition de petits segments intestinaux à la paroi abdominale. Les auteurs étudient l'intérêt de ces résultats.

REFERENCES

Bergstrand, I., and Ekman, C.-A.: Portal circulation in portal hypertension. Acta radiol. 47 (1957), 1.

Bruusgaard, C., and Funder, R.: Operative treatment of ascites. Nord. Med. 60 (1958), 1587.

Doehner, G. A., Ruzicka, F. F., Rousselot, L. M., and Hoffman, G.: The portal venous system: On its pathological roentgen anatomy. Radiology 66 (1956), 206.

Ferrer, Jr. J. M.: The use of a transplanted segment of ileum as an absorbing pouch for cerebrospinal fluid in congenital hydrocephalus. Congr. Int. Surg. München 1959.

Madden, J. L., Loré, Jr. J. M., Gerold, F. P., and Ravid, J. M.: The pathogenesis of ascites and a consideration of its treatment. Surg. Gynec. Obstet. 99 (1954), 385.

Miller, T. R., Grossi, C., and Lewin, E.: Parasitization of isolated small bowel loops in dogs. Surgery 44 (1958), 402.

Neumann, C. G., and Richman, H.: Studies on the mechanisms of control of ascites by means of ileo-entectropy. Plast. reconstr. Surg. 20 (1957), 379.

— Adie, G. C., and Hinton, J. W.: The absorption of ascitic fluid by means of ileo-entectropy in patients with advanced cirrhosis. Ann. Surg. 146 (1957), 700.

— Hoen, T. I., and Davis, D. A.: The adaptation of ileoentectropy to the control of congenital communicating hydrocephalus. Plast. reconstr. Surg. 123 (1959), 159.

— Braunwald, N. W., and Hinton, J. W.: The absorption of ascitic fluid by a pedicled flap of intestinal mucosa exposed within the peritoneal cavity. Plast. reconstr. Surg. 17 (1956), 189.

Nylander, P. E. A., and Turunen, M.: Transposition of the spleen into the thoracic cavity in cases of portal hypertension. Ann. Surg. 142 (1955), 954.

Talma, S.: Chirurgische Öffnung neuer Seitenbahnen für das Blut der Vena porta. Berl. klin. Wschr. 35 (1898), 833.

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THE AUTOMATIC EXPOSURE TIMER AS A BASIS FOR AUTOMATION IN ROENTGEN WORK

by

F. E. Stieve

During the Seventh International Congress of Radiology at Copenhagen, HILLS (1954) closed his lecture with the following words: 'To conclude, phototiming is the method of choice for the accurate control of chest roentgen exposures, but owing to the relatively high speed at which such exposures should be made, this branch of photoelectric control has its unique problems.'

He was dealing principally with radiography of the chest, since he believed that 'the photoelectric control of roentgen exposures is probably of greater importance in the examination of the chest than of any other region'.

During the past six years such great strides have been made in the technical development of exposure timers, and their scope of application has correspondingly been so extended, that it seems opportune to survey the present position and to report on experience gained in the interim.

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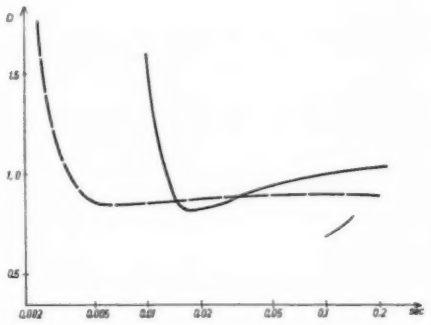

Fig. 1. Lowest limits of switching-time of two automatic exposure timers on 6-valve X-ray sets, determined by density measurement. By this is understood the time at which the blackening of the film begins to be visible against the background level.

———— 6-valve set with double relay switching

— — — — — — — — — 6-valve set with mechanical-electronic relay switching.

Present state of development. As the most important progress we may mention the reduction of the minimum exposure time. In 1953 HILLS stipulated 50 msec as the shortest exposure time for lung exposures; using suitable apparatus, this figure can now be cut down by a factor of ten and, according to our experience, is still adequate using voltages up to 150 kV to provide sharp images in any type of exposure, and to make use of the full capacity of the set and tube.

The question of the shortest exposure time is not so much a problem of the automatic timer itself as of the roentgen unit, since automatic timers pass the triggering impulse to the switchgear of the set electronically, i. e. practically without inertia. If the switching sequence in the set also takes place electronically via devices in the HT circuit at constant DC, then there is from the viewpoint of the equipment no lower limit to the switching time. Equally short switching times can also be achieved (CHELAZZI) by means of electronic switching in the primary circuit (thyratrons). Since there are, however, practically no commercially-available roentgen units incorporating such electronic devices, the lower limit of switching time is dependent upon the inertia of the relay switches. Without special arrangements, this inertia permits automatically-timed exposures down to a minimum time of only some 50 msec. A certain improvement can be obtained using the compensation circuit system developed by MEILER (1940) — a system by which, with short exposure times, the cut-out signal is given before the required dose has been received. This advance passing of the cut-out signal thus compensates for the delay in the relay operation. Attempts have recently been made to reduce the cut-out time by additional electronic means to such an extent that the shortest auto-timed exposure times using relays are of the same order as the shortest times without an auto-timer (cf. Fig. 1). For various technical

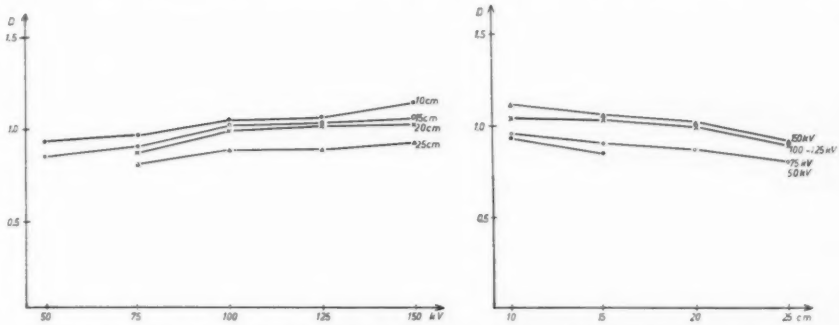

Fig. 2. Voltage and thickness dependence in an ionometric measuring system.

reasons, however, such short auto-timed exposures have only been obtainable on 6-valve sets, a fact which provides a further cogent argument for the use of a three-phase supply equipment.

Many automatic timers are provided with a warning system which calls attention to any falling-short of the shortest time leading to overexposure of the film.

Another improvement is to be seen in the great extent to which voltage dependence has been overcome.

In the earlier systems, from the ionometric auto exposure timer of FRANKE to the photoelectric systems of MORGAN and HODGES, HILLS, and others, the measuring unit was placed behind the cassette. They were thus affected by the attenuation of the radiation passing from the patient through cassette, screen and film; and this rose sharply with increasing voltage. Since, however, the quality of the emergent radiation is, at the same primary radiation voltage, also dependent upon filtering by the subject, there is, in addition to the dependence on the exposure voltage, another dependence on the thickness of the subject, for the average density of films is less for thick subjects than for thin ones. This had already been noted by HILLS.

The introduction of the shadowless chamber for the ionometric automatic exposure timer (BISCHOFF) and later for the photoelectric system (LOHMANN et coll.) made it possible to place the measuring unit in front of the cassette, overcoming this voltage phenomenon to a very large degree; and in addition this offers very considerable advantages in working method — during fluoroscopy the viewing field remains unimpaired, and during exposures there is a greater range of tolerance for the position of the cassette, quite apart from the fact that special cassettes are not called for.

In the general use of the auto exposure timer, however, recording the middle density alone is not enough invariably to provide optimally exposed roentgenograms. To achieve uniformity in the exposures it is also necessary to keep the scatter component of the radiation (which is dependent on the type of subject and the size of the field) as constant as possible for each exposure since, according to experiments carried out by SPIEGLER, contrast at a standard exposure voltage depends upon the scatter component of the total radiation striking the film. Practice has shown that this dependence is far greater than that of the contrast upon the exposure voltage.

The greatest possible constancy of the scatter component may be obtained by reducing the production of scatter by limiting exposed area, and to a large extent eliminating what scatter there is by means of a high-efficiency grid; this means that in general all exposures should be made using such a grid.

In the techniques used up to now, making exposures partly with and partly without a grid, depending on the nature of the subject, the scatter component varies between about 10 to 30 % in radiography with grid and between 50 to 70 % in radiography without grid. If a grid is used for all exposures, the scatter component varies between only 8 and 30 %. This not only makes for more uniform exposures, but also improves the contrast (and, consequently, the detail resolution) through the reduction in the scatter component. Furthermore, the limitation of the varying relationship of primary radiation to scatter radiation also contributes to the evenness of auto-timed exposures. The possibility of obtaining automatically exposed roentgen films rests, of course, on the fact that the diagnostically important areas of all roentgenograms call for the same average density, and that this is obtainable — photographic factors being equal — by the same average dose to the area. The proportionality of the dose behind the subject to that on the film is governed largely by the percentage of the total radiation which is present at the measuring position in front of the film as scatter radiation. This can be explained by the fact that because of the short distance from the source of the scattered radiation and its random path, the level of scatter at the measuring position is greater than at the film further back. Quite aside from this, when cassettes and screens are used scatter radiation produces a much lower degree of film blackening than an equal amount of primary radiation, as has been shown by WIDENMANN (1957). A probable explanation is the oblique penetration of the intensifying screens by the scattered radiation, which therefore of course decreases more rapidly.

If, now, we arrive by use of the grid at a position where the radiation striking the measuring unit is predominantly primary radiation, all that remains to affect the film density is any voltage dependence on the part

of the measuring unit. Since this, however, is governed by the exposure voltage and (unlike the scatter effect, which is hard to assess in practice) can thus be defined for the measuring unit involved, dependence can be taken into account by an automatic sensitivity adjustment for the measuring system, coupled to the voltage regulation of the set. In this way, using a modern auto-timer, all exposures can be made from the same control position with only one preset sensitivity.

Phantom tests under these conditions give the following picture: during exposures without a grid, the blackening between 50 and 150 kV with equal phantom thickness and field size remains constant (as other measurements by STIEVE, ZIELER and LOHMANN have shown) since the proportion of scatter radiation behind the phantom at a constant emergent dose is practically invariable. Any voltage dependence peculiar to the measuring unit does not appear, since the relatively high scatter radiation component (over 50 %) brings about a balancing of the radiation quality. With increasing phantom thickness, on the other hand, the intensity of exposure decreases at the same voltage (by about 30 % between 10 and 25 cm), since the scatter component becomes larger.

During exposures with an efficient grid, there is still a dependence on thickness of about 15 %. The increase in blackening, with equal phantom thickness and field size, with increasing voltage is about 30 % between 50 kV and 150 kV (Fig. 2). This increased blackening, governed by the voltage dependence of the measuring system, could, as we mentioned earlier, be quite simply compensated for by the voltage regulation of the roentgen equipment. The increase in average film density is nevertheless desirable in exposures using higher voltage, since the flattening of contrast met in exposures at high voltages will make the images seem subjectively too soft. The brilliance of roentgen films is found by experience to be judged from the darkest parts.

According to test measurements made by LOHMANN a similar trend of film density, dependent on exposure voltage and subject thickness, can also be observed with the photoelectric systems.

A permanent positioning of the measuring unit in front of the cassette involves a limitation to a small number of measuring fields, since it precludes an alteration in the area of the measuring field by a partial shielding such as is possible with MORGAN's automatic timer. This means that its size and arrangement must be given a very precise consideration and calculation. Every roentgenogram has one zone, called the 'dominant' by FRANKE, the density of which is critical for the optimal density of the film. In a correctly exposed roentgen film no matter what the type, the average density should lie in the centre of the tonal range, i. e. (with the normal range of from $D = 0.2$ up to $D = 1.8$) somewhere in the region of $D = 0.9$. This is the value found by MORGAN in roentgenograms

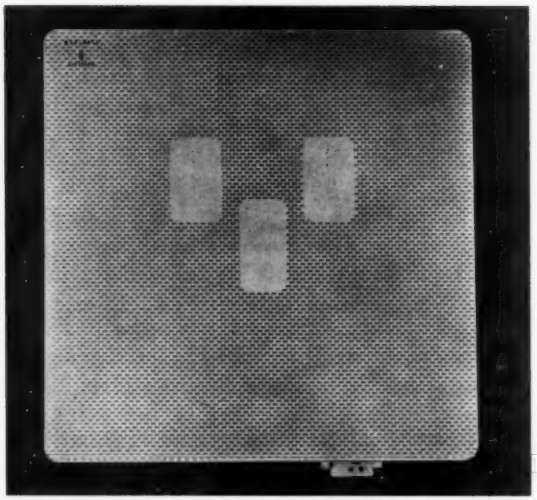

Fig. 3. Ionometric measuring chamber with three-field layout.

of the lung. The size of this zone is different for each exposure. Two factors are of major importance in the design of a universally applicable measuring field; on the one hand the field must be large enough to be genuinely capable of embracing the average value of the important areas of all roentgenograms, and on the other it must not be larger than the smallest dominant, since this will in many cases be immediately adjoined by an area of totally variable transparency (e. g. thoracic vertebrae, cervical vertebrae, extremities, etc). As almost all organs show a greater length in the axis of the body than across it, the measuring field takes on an oblong or oval shape in the centre, with longitudinal extension along the body axis. It was shown, by a statistical evaluation of the mean values from 100 roentgenograms each of all the types of subject involved, that the dimensions when making Bucky table exposures should be about 4×8 cm, and up to 5×10 cm. Apart from the measuring field which lies in the central beam and is suitable for all cases in which the organ to be radiographed is centrally located, other fields outside the image centre are required for those views where the diagnostically important parts are pairs of organs located on either of the symmetrical axis (such as, for instance, the lung, kidneys and pelvis). Here again an upright oblong of some 40 to 50 cm^2, with the central point displaced laterally and cranially, has been found suitable. Each of these fields must be able to be used independently of the others.

Even for lung radiography only one field should be used as a general rule, especially in the case of unilateral pathologic symptoms, since if the fields for both sides are used simultaneously, the integrated measurement will lead to under-exposure of the diseased side and over-exposure of the healthy lung. From these requirements we arrive at an arrangement of three fields, which has proved itself during my personal experience in practical use with a universal application of the automatic exposure timer. Fig. 3 shows this arrangement on an ionometric system.

Auto-exposure-timers

As ZIELER has already demonstrated, the introduction of a generally usable automatic exposure timer seems, in view of the present stage of development, an obvious step, bringing a far-reaching rationalization of roentgen diagnostic work via a standardization of the exposure technique. This is all the more true since the first move has already been made through the necessity of using a grid for all exposures, and of settling upon a uniform sensitive material of known characteristics coupled with an unaltered processing procedure. All that remains, therefore, is to find for every radiographic subject a combination of control settings which will provide the best possible roentgenogram with all patients, making the fullest use of the capacity of the equipment and the roentgen tube. As we know, the quality of a roentgenogram is largely dictated by the contrast and the sharpness; from the apparatus side the contrast is determined by the exposure voltage, and the sharpness is determined (besides by the photographical factors, e. g. focus size and screens) by the exposure time. The exposure time, again, depends on the capacity of the roentgen tube, i. e. it is related to the voltage and the current level. Now, since the exposure time decreases with increasing voltage, despite the necessary reduction in current level (due to the loading capacity of the tube), any desired switching time can in theory be achieved for any organ by using a certain voltage value. Practical limits to this are set by the performance of the roentgen equipment, and there is additionally an increasing flattening of contrast with increased voltage. When settling upon standardized control settings, therefore, the radiographic subjects must be subdivided depending on whether a short exposure or contrast is the more important from the point of view of picture quality. The first group will cover organs exhibiting a large degree of individual movement, such as lungs, intestines and heart; the second includes all the bones. Between the two there lies a third group, for which both excessive voltage and over-long exposure time will be detrimental; these are the organs with relatively little movement, which are demonstrated by means of iodine-content contrast media, in particular the kidneys and the gall-bladder.

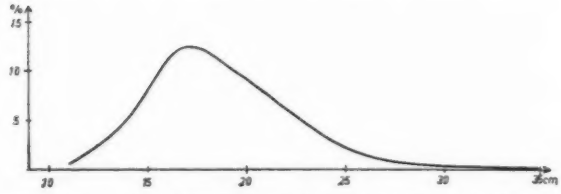

Fig. 4. Proportional distribution of the sagittal diameter of the abdomen in 300 adult patients.

It was mentioned in the opening paragraphs that HILLS stipulated times of about 50 msec for radiography of the lungs; in my experience they should be no longer than 30 to 50 msec, and the same is true for the stomach and intestines.

Measurements on 300 patients have shown that in abdominal examinations on adults sagittal diameters vary from 13 cm to 30 cm, the average being 19 to 20 cm (see Fig. 4). (These and subsequent data refer of course to subject thicknesses of patients seen here, and there will undoubtedly be regional variations.)

We shall now first of all indicate conditions suitable for the group consisting of patients having approximately the normal diameter. It should be noted here that, even with the same subject thickness and field size, scattering of the required exposure radiation will occur due to the structure of the subject, made up as it is of a mixture of bone, muscle, fat, gas, etc. Fig. 5 shows the mAs product obtained with the automatic exposure timer on 50 patients of equal diameter using three voltages: at 75 kV the values differed in 90 % of cases over approximately 53 % around the average of 8.5 mAs, at 100 kV over some 47 % around an average 4 mAs, and at 125 kV over 45 % around the mean of 2.3 mAs.

These results not only demonstrate how considerably the exposure data fluctuate for the same patient thickness (and this alone would already justify the use of an auto-timer) but also show that differences in transparency decrease with rising voltage. This becomes evident by the increase in height of the columns of equal areas. Since the width of the columns (= varations in the mAs-values) is given logarithmically, equal distances on the x-axis correspond to equal percentages despite differences in absolute mAs-values. We shall thus select the voltage and current values for these normal patients so that the lowest mAs product expected will correspond to the lower switching-time limit of the automatic timer. Since, however, abdominal examinations are not restricted to exposures in the sagittal diameter, it remains to be checked beforehand whether even lower mAs values cannot be achieved by spot

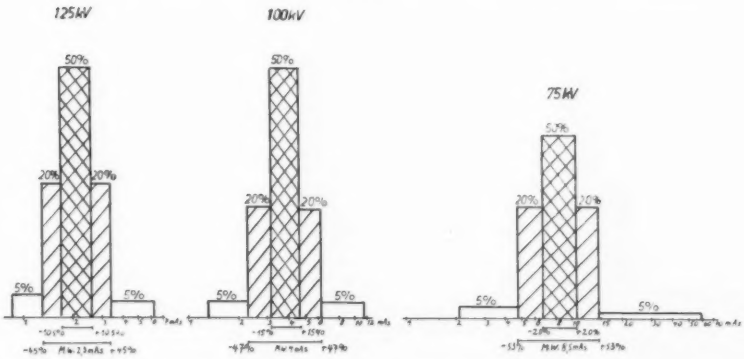

Fig. 5. Proportional distribution of the mAs value in p. a. exposures of the upper abdomen with a sagittal diameter of 20 cm and a constant field size of 18 cm × 24 cm, at kilovoltages of 75, 100 and 125 kV, respectively.

exposures with compression. Fig. 6 shows the mAs values obtained with an auto-timer at an exposure voltage of 100 kV during complete abdominal examination on 50 normal patients with a sagittal diameter of 20 cm. They vary between 2.5 and 25 mAs, the overall views in a recumbent position giving the lowest values while the highest mAs product figures were obtained with spot exposures, despite compression, on account of the usually reduced field area. (All the data on exposures with the spot film device relate to a six-valve set used in conjunction with a 30 kW tube, those with the Bucky table or Bucky wall stand to the same set with a 50 kW tube).

Since, now, the exposure generally needs increasing or reducing by a factor of 1.25 for every centimetre difference in thickness, while individual variations at the same thickness have a factor of almost 10, thickness variations over approximately 5 cm can be quite simply gathered in one group, i. e. that of normal patients of 17 to 22 cm. The majority of all exposures for a complete abdominal examination for this group lie between 4 and 20 mAs. Since the tube current permissible for this is in the region of 300 mA, the stipulated time can be maintained for this thickness group, from 17 to 22 cm. The settings on the equipment will therefore be (allowing for a safety factor) 100 kV, 300 mA and 40 mAs.

The other groups lying above or below this diameter can again be divided into groups spanning 5 cm thickness difference each. Their mean values will then be 15 cm for slim patients and 25 cm for stout subjects. The voltages required for the same exposure time will be seen from Figs. 7 and 8. Fig. 7 shows first the incident and emergent doses for water

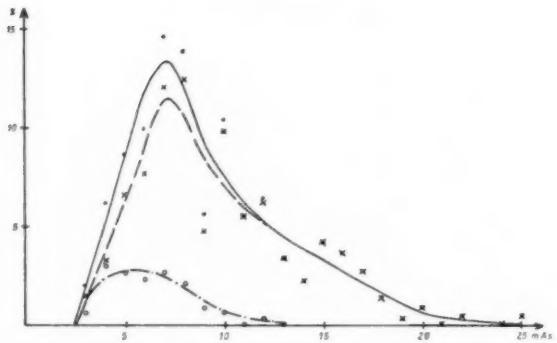

Fig. 6. Proportional distribution of the mAs value in 50 complete stomach examinations in patients with a sagittal diameter of 20 cm. The entered values are according to measurements. The resulting distribution curves were calculated by means of generally accepted statistical methods.

·———· percentage distribution of mAs value in all exposures (340)
°—·—·—° percentage distribution of mAs value in exposures in supine position (50)
× — — × percentage distribution of mAs value in spot exposures (290)

phantoms of 15, 20 and 25 cm thickness (found by measurement to correspond roughly to an abdomen of the same diameter), related to the same dose behind the grid depending on the voltage, with a FFD of 150 cm; it also shows the mAs products required for these. Fig. 8 indicates the times necessary for the mAs values of Fig. 7 with a full load on the tube (50 kW tube). (The mAs product and time will, admittedly, alter in exposures with the spot film device at minimum distance and a 30 kW tube, but the relationships as a function of the thickness remain unaltered). The voltage level of 100 kV set down for normal patients is thus matched by 70 kV for slim and 135 kV for stout patients. In the case of very fat patients, i. e. over 27 cm diameter, the recommended procedure is not only to step up the voltage but also, sacrifizing geometrical sharpness, possibly to adopt a larger focus which will permit a higher current level; this will enable the same short exposure time to be attained.

Gross errors in adjustment (such as an exposure time lower than the shortest possible, or a too low pre-set mAs figure) are indicated by a warning device in the auto-timer; a more accurate check on the accuracy of the settings selected can however only be obtained from the reading on the mAs meter or by reading the time selected. For this reason all sets which are not fitted with a mAs meter should at least have a time meter.

If the considerations and calculations listed here for the abdomen

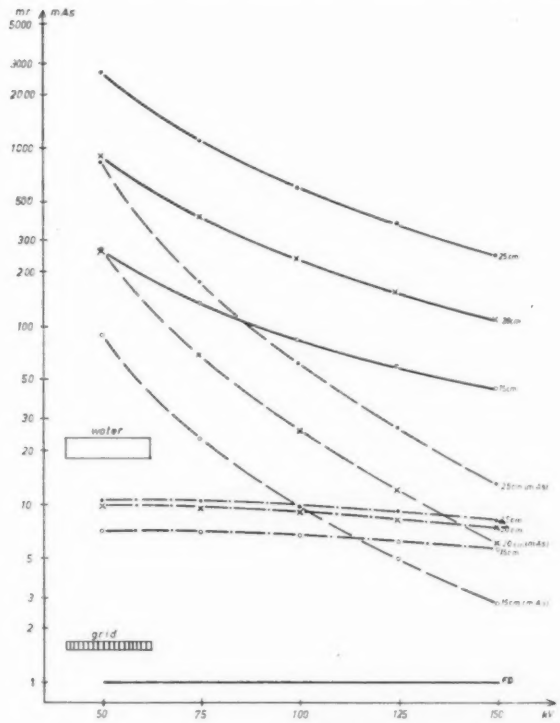

Fig. 7. Incident dose (———) emergent dose (—·—·—) and mAs value (— — —) as a function of the exposure voltage, related to a constant film dose (F. D.) of 1 mr behind a movable scatter grid (15 : 1) with water phantoms of 15, 20 and 25 cm diameter, using a field 30 cm × 30 cm and a FFD of 150 cm.

are applied to chest exposures, we see that here again three groups may be distinguished (Fig. 9), such that the normal patient has a thoracic diameter of 22.5 cm, the stout patient 27 cm and the thin patient 18 cm. For soft exposures with the scatter grid we find voltage groups of 50, 60 and 75 kV and a control panel setting of 50 mAs at 1 000, 900 and 700 mA respectively, for high kilovoltage technique, 100 and 150 kV with a setting of 20 mAs at 500 and 300 mA. These figures were obtained taking into account the scatter occurring with 100 patients of equal thickness. Unless a basic voltage setting of 150 kV is employed, a further setting combination of 90 kV, 50 mAs and 600 mA should be reserved for chest exposures involving lung tissue not containing air. The exposure tolerance in such a case must be rather larger than with other organs, since

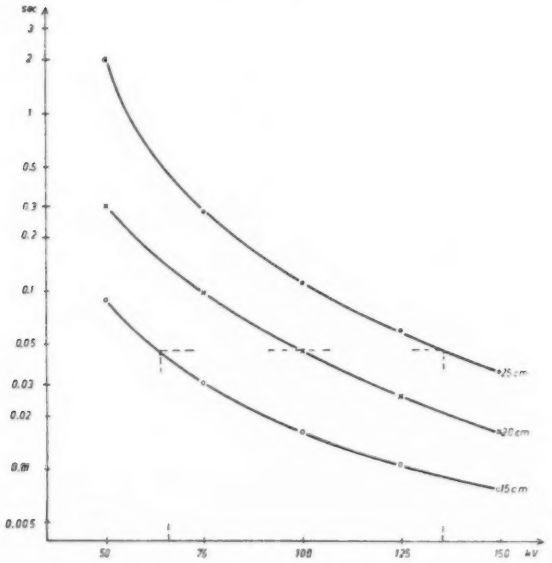

Fig. 8. Switching-times resulting from the mAs values given in fig. 7, with a 50 kW tube fully loaded. From here can be read the alterations in voltage required at the various phantom thicknesses in order to arrive at the same switching-time.

it is extremely difficult accurately to assess the relationships of air and tissue in the thoracic cavity. A similar sub-division is possible in this way for radiography of the gall-bladder and the kidneys although the voltage must then not be taken too high for fear of an excessive loss of contrast. An exposure time of under 0.25 sec is generally sufficient to prevent difficulties due to respiration.

In radiography of the bones only two kV divisions are necessary to allow for subjects with substantial differences in thickness (thoracic and lumbar vertebrae, pelvis), with the object of keeping down the dosage on stout patients and observing the loadability rating of the tube. For other bones, such as the cervical vertebrae, skull and extremities, a single voltage setting is adequate. All that is necessary then is to decide on the highest mAs value which will occur, allowing a safety increment of about 50 %.

On a six-valve apparatus with voltages up to 150 kV, the standardized exposure technique (using a 30/50 kW tube, hard radiation grid with a constant FFD of 150 cm for Bucky table exposures, and a standard grid (ratio 7:1) and normal FFD for spot-film devices) will appear as in Table 1.

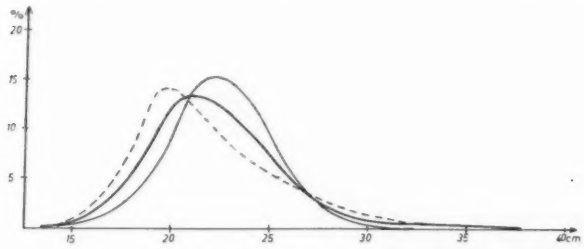

Fig. 9. Proportional distribution of the sagittal diameter of the thorax at maximum inspiration in 300 adult patients.

– – – – Men ———— Women ———— Total

This system of sub-division has been found thoroughly satisfactory over a long period of practical use.

I feel that there is still value in discussing, in connexion with spot-film examinations, the question of whether the voltage may not be automatically varied with patient thickness by means of a variable resistance connected to the 'to and fro' movement of the spot-film device, which would continuously alter the voltage set on the control panel by an amount matching the increase in thickness. Suggestions on these lines were made by both HARNICK and LUSTED even before the introduction of the automatic exposure timer, and it is said to have proved satisfactory in practical use. It will be seen from Fig. 10 however, that in the individual abdominal roentgenograms there is absolutely no proportionality between the distance of the screen from the table surface and the mAs product selected. Because of the ellipsoidal transverse diameter of the body the increase in distance does not correspond with the extra thickness of tissue produced by revolving the patient. At the same time divergences arise with an equal-irradiated body thickness between exposures made with and without compression, since only the substance causing the least amount of attenuation (fat and air) are moved to one side during compression and for both these reasons I feel that a voltage compensation of this kind would not serve our purposes.

Since the automatic exposure timer must (unlike nonautomatic switching) be allowed a sometimes very substantial exposure tolerance, involving in some circumstances up to ten times the normal mAs value, there still remains the question of whether under these conditions we are still making the best use of the tube and to what extent we are falling short of the permissible loading of the tube. This problem has been very fully dealt with by SCHOTT. Fig. 11 shows the load chart for a 30 kW

Table 1

Exposure times and mAs values set and switched on a 6-valve set with 30/50 kW tube, using high-speed film (e. g. Kodak Regulix) and a universal screen (Siemens Saphir)

Organ	Diam. (cm)	Values set[1]			Values switched[2]	
		kV	mAs	mA	mAs	Time in sec
A: Exposures with the Bucky table or wall-stand						
FFD = 140 cm, scatter grid FFH (ratio 12.5: 1), 50 kW focus						
Lung p.a.	14—18	50	50	1 000	20—40	0.02 —0.04
	19—24	60	50	900	10—40	0.011—0.045
	25—29	75	50	700	8—30	0.011—0.045
Lung p.a. & pathol.	20—	100	20	500	3—12	0.006—0.024
	20+	150	20	300	3—12	0.010—0.040
Lung p.a. pathol.	20—	90	50	600	10—40	0.017—0.07
Lung lat.	21—25	70	120	700	30—90	0.04 —0.125
	26—31	80	120	600	40—90	0.065—0.145
	31+	95	120	500	20—100	0.04 —0.20
Abdomen a.p. (kidneys, gall bladder)	12—16	55	200	800	80—150	0.07 —0.17
	17—22	65	200	700	40—150	0.06 —0.21
	23+	80	250	500	40—250	0.07 —0.38
Skull p.a.					90—220	0.15 —0.37
» lateral					25—120	0.04 —0.20
Cerv. spine p.a.					35—100	0.06 —0.17
» lateral					30—120	0.05 —0.20
Shoulder		70	250	600	30—90	0.05 —0.15
Knee joint					15—40	0.025—0.07
Thor. spine p.a.	20—				30—200	0.05 —0.34
» lateral	28—				30—200	0.05 —0.34
Lumb. spine p.a.	19—				40—200	0.07 —0.34
Pelvis	19—				40—180	0.07 —0.30
Thor. spine p.a.	20+				60—200	0.12 —0.40
» lateral	28+	80	250	500	40—200	0.08 —0.40
Lumb. spine p.a.	19+				40—200	0.08 —0.40
Pelvis	19+				50—180	0.10 —0.36
Lumb. spine a.p.	28+				50—180	0.12 —0.45
Pelvis	28+	95	200	400	50—180	0.12 —0.45
Skull, axial					40—120	0.10 —0.30
Lumb.spine lateral		130	250	250	40—200	0.16 —0.80
B: Exposures with spot film device						
FFD = approx. 50 cm, scatter grid FF (ratio 7: 1), 30 kW focus						
Stomach & barium enema	12—16	70	40	450	4—30	0.009—0.07
	17—22	100	40	300	2—30	0.007—0.10
	23—27	135	40	200	2—30	0.01 —0.15
Rectum lateral		135	60	200	3—50	0.015—0.25
Gall	12—16	60	60	500	20—40	0.04 —0.08
	17—22	65	60	450	8—50	0.018—0.11
	23+	80	75	300	15—50	0.05 —0.17
Oesophagus	20—	70	40	450	5—25	0.011—0.055
	21+	100	30	300	5—20	0.017—0.07
Trachea a.p.		70	40	450	4—25	0.009—0.055
» lateral		135	40	200	10—20	0.05 —0.10

[1] On sets with automatic kV setting full load always equals 100 % tube loading; on sets with current selection (recording technique) the currents quoted are a guide.

[2] The switched times are calculated for 100 % tube loading.

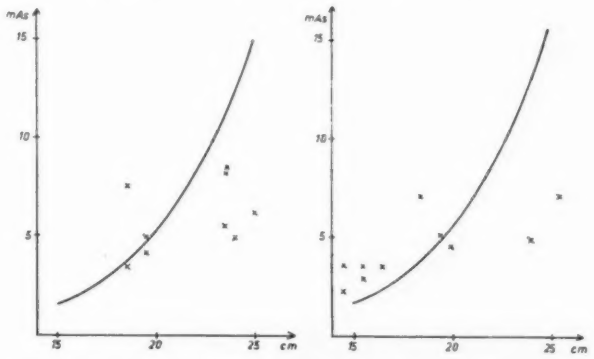

Fig. 10. mAs values measured during 2 abdominal examinations (100 kV), as a function of the smallest possible distance between base plate of stand and the screen. If this distance were proportional to the patient diameter in each case, the switched values would necessarily lie on the curve.

tube with lower loads as well as the curve for 100 % load. We see from this that during short exposures, especially in high kilovoltage technique, where the best possible utilization of the tube capacity is aimed at, the tube is never less than 95 % loaded with a switching time of up to 100 msec, even when the actual switched time is only 10 % of what was preset. Also for exposures at lower kilovoltages, for instance in the case of spot exposures of the gallbladder, which in our institute are made at 65 kV with a pre-set 60 mAs corresponding to 0.12 sec with the 500 mA permitted, in order to give the necessary contrast, the tube is still loaded to 90 % at the lowest observed value of 8 mAs (corresponding to 0.016 sec.)

With longish exposures, on the other hand, the percentage utilization of tube capacity varies. Thus, in the case of a roentgenogram of the lateral lumbar vertebrae, with 130 kV and 250 mAs (= 1 sec at the permissible level of 250 mA) on a patient requiring only 20 % of the values set in (40 mAs in 0.2 sec), the tube was still 75 % loaded. This fact is however without any practical significance, since the spine has no individual movement and ultra short exposure times are consequently not imperative.

If then we bear in mind that all roentgen films, where the switching time is of importance, are exposed at less than 0.2 sec, the question of whether an auto-timer permits full use to be made of set and tube must be answered in the affirmative. For radiography, where the exposure time is of no major importance, the use of this technique will even in certain circumstances entailing a lesser loading save wear on the tube.

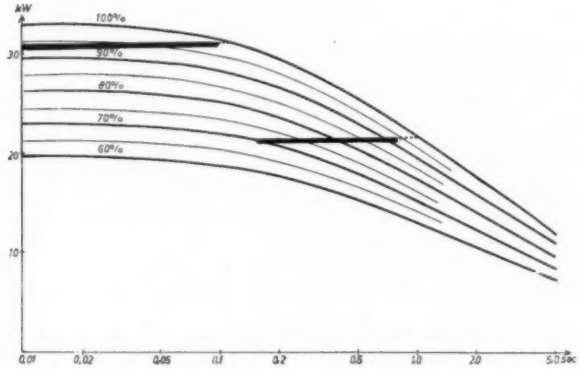

Fig. 11. Loading chart for a 30 kW tube in a 6-valve set, for loadings of 60 to 100 %. The examples shown correspond to the conditions met in examinations of the abdomen (100 kV, 4 to 30 mAs), and of the gallbladder (65 kV, 8 to 60 mAs) — upper black bar —, and in exposures of the lateral lumbar spine (125 kV, 40 to 200 mAs) — lower black bar.

Practical application and possible errors

To use the automatic exposure timer the basic rules governing the technique of radiographic exposure must be fully understood and sensibly applied. The same dictum is true here that holds for photography in general: using an exposure meter is not enough by itself to give good pictures. There is no doubt that in the general run of practical work without an auto-timer the basic rules are to a large extent insufficiently observed. The errors which result can, so far as possible, be allowed for in processing, although this means that the optimum image quality can no longer be obtained. With automatic processing, however, the balancing-out of such errors is impossible — quite apart from the fact that stricter criteria are unconsciously applied to the results of mechanical processing than to the subject assessments. For this reason faulty exposures are very frequently put down to malfunctioning of the auto-timer, instead of to the real reason, which is bad exposure technique. We can rapidly survey the principal possibilities of error in exposure; an exhaustive treatment has already been made elsewhere (STIEVE, WIDENMANN).

Practical experience has shown that one basic statement must be made at the beginning; a statement which, while it sounds self evident, is very frequently the subject of misunderstanding: the measuring field records the radiation passing through the grid practically irrespective of its hardness, to an extent corresponding to the sensitivity setting of the measuring

system. An increase in the voltage thus never leads to a higher film density, only to an equal exposure over a shorter time period. If higher density is called for, it can only be achieved by an alteration in the sensitivity setting of the measuring system.

1. Measuring field. Correct exposures are only arrived at when the measuring field lies in the region of the dominant. When carrying out radiography where there is no fluoroscopic check the measuring field must therefore be projected onto the patient by means of a collimator, with the tube and Bucky diaphragm coupled. Bucky diaphragms in fixed positions (wallstands) marking the measuring fields on the cover of the diaphragm has been found very useful.

Exposures of the abdomen and the hip joints should invariably be made with a lateral field. It is true that the variations in thickness over the centre of the subject are small, but the transparency of the tissue can vary greatly as a result of a differing distribution of fat, gas and bone.

Apart from this the radiation penetrates lateral regions obliquely and is consequently more strongly attenuated in the subject and in a grid whose laminations are not perfectly centred; these parts can therefore be underexposed when the exposure is controlled by the central field.

A certain amount of difficulty is caused by subjects with large differences in thickness along the body, such as the trachea or the lumbar spine including the os sacrum in the latero-lateral aspect. It is pointless to adjust the setting for the transitional area, since this will give an exposure which is too small for the thick part and too large for the thin part. Either two separate roentgen films must be obtained in such a case, or else the differences in thickness must be compensated by differential filters or a rotating screen over the thinner part (GAJEWSKI). A suitable copper filter for the trachea has recently been provided by ZIMMERMANN.

It is most important that the measuring field should be shielded against any radiation which has not been attenuated via the subject; since even behind the grid this will have a very much higher intensity than the image-forming radiation which has passed through the subject, it will produce a very substantial under-exposure.

Scatter radiation occurs in every object struck by the roentgen rays, including therefore the patient's support, the grid and the chamber housing the measuring field. If the radiation which is unattenuated by the subject is very intense, scatter produced in the various parts mentioned can reach a level where it equals the exposure radiation. When it reaches the measuring field, under-exposure is the inevitable result, not to

mention poor contrast in the roentgenogram (STIEVE). A very narrow defining of the exposure field is thus necessary, and this can best be arranged with additional shielding close to the subject, using lead rubber. This is particularly important for subjects with curved peripheral areas; a suitable shielding device has been produced by VOGL and ZEIDLER.

This defining must not, however, be smaller than the active measuring area; shielding to less than this area will bring about over-exposure. When using a spot film device it is possible in such cases to arrange an alteration in the sensitivity of the measuring system for fixed field sizes, operating from the set itself (e. g. by means of a contact made through the insertion of the cone).

2. Sensitive material. Absolutely standard characteristics in film and developer materials have been so frequently stressed, and the need for them is so self-evident, that they need no further discussion here. We might, however, mention one point; it has been found best to use a contrasty film. The use of a grid calls for much more exposure, and in order to allow of short exposure times this must usually be obtained by a considerable increase in the voltage. Since this would affect the quality of many roentgenograms through the consequent lessening of contrast, this must be allowed for by the use of a film with a steep curve, and by a contrast-producing developer.

3. Development. Experience with automatic exposure timers stretching over almost nine years has shown that the main source of unsatisfactory image quality lies in defective film processing. Films must be developed in a standard quality developer at a constant temperature for a standard length of time (without visual inspection). This is, of course, best achieved in automatic processing units, and the use of automatic exposure timers in fact calls for them as a necessary concomitant. Unfortunately there has up to now been a lack of suitably priced machines particularly for the small and medium-sized roentgen department, e. g. semi-automatic units functioning up to the fixing bath stage, and which could be installed in an existing set-up.

Developing plants in departments using automatic exposure timers must in every case (i. e. whether or not there is mechanical transport of the films) be fitted with a thermostat and a replenishing device; variations in temperature and in the strength of the developer not only lead to uneven roentgenograms but they make a mockery of any attempt at rationalizing the work of the dark-room. The finding of FREY, STANFORD and others have shown the necessity of these stipulations. It must nevertheless be noted that thermostat installations do not invariably do what is required of them under all circumstances. The effect of the heating

element may be too weak when there is a strong flow of rinsing water through the bath, or the installation may be wrongly employed (e. g. switched off during the night). The latter is most definitely to be avoided, since a very long time is required both to warm up the rinsing bath and, particularly, to achieve evenness of temperature between the developer solution and the rinsing water (in which the temperature is usually measured). A difference of only 1° when the standard temperature is 20° C means an alteration of some 15 % in film speed with the same developing time.

4. Screens. There are two points to be borne in mind in connexion with intensifying screens: firstly, constant sensitivity, and secondly, a possible dependence of density on voltage with an equal dose at the film. From the point of view of constant sensitivity the same considerations apply as for films; so far as feasible, one make and one type of screen should be used. When arranging the original assortment of screens, and even more when supplying extra screens, care should be taken that they are of equal sensitivity. Many manufacturers tend, at certain distances, to arrange for different sensitivities and thus different screen properties.

It is true that various types of currently available auto-timers incorporate some simple device (such as push-buttons) allowing variations in the sensitivity of the photographic material to be accommodated without altering the fixed sensitivity setting of the measuring system. Since this type of sensitivity adjustment to the measuring system provides for only definite percentages of the set value, it is doubtful whether these would correspond with the variations in sensitivity in different types of screen.

The majority of screen combinations give a constant film density for an equal applied dose with the radiation levels used in diagnostic work; the only exception is the type of screen providing a high degree of intensification. With these the density increases with higher voltage at the same dose. Such screens are thus unsuitable for use with automatic exposure timers, or should only be used within a limited range of higher voltages (upwards of approximately 100 kV) with appropriately increased sensitivity settings in the measuring system.

The experience reported here has shown that it is imperative to use photographic material of constant characteristics; it emphasizes above all the necessity for settling upon standardized sensitivity ratings for all materials (films, developer and screens), which should be measured and marked on the packing in every instance. Proposals for suitable standards are being drawn up at the present moment by the ICRU.

The use of an automatic exposure timer, by improving the quality of roentgenograms and simplifying the procedure, which relieves the radiographer of subsidiary tasks (which are frequently very time-consuming, and detract from concentration on the major task of exposure technique), brings such decisive advantages that my experience puts me unreservedly in favour of its general adoption.

Acknowledgements

I should like to express my gratitude to Miss L. WIDENMANN for her help in experiments, especially with dose measurements. My thanks are also due to Mrs. M. VOGL, Miss K. BOES, Miss G. KOLBERG and Miss M. RÖSLER, who undertook the measurements of patients.

SUMMARY

Technical developments in the field of automatic exposure (shortening of exposure times, non-dependence of the measuring system on voltage and subject thickness and modification of the measuring field lay-out) now make it possible for roentgen diagnostic work to be rationalized through a standardization of the exposure technique. The measures needed for this, which include the calculation of groups of exposure settings for subjects guaranteeing the best possible radiographic quality, are discussed on the basis of measurement data and many years of practical experience. Finally a number of the errors most frequently occurring in practical work are pointed out.

ZUSAMMENFASSUNG

Technische Fortschritte auf dem Gebiet der automatischen Exponierung (Verkürzung der Exponierungszeiten, Unabhängigkeit des Messystemes von Spannung und Dicke des Subjektes, und Modifikation des Messfeldes) machen für die röntgendiagnostische Arbeit eine Rationalisierung durch Standardisierung der Exponierungszeiten möglich. Die dafür nötigen Messungen, einschliesslich der Berechnung der Exponierungen, die mit Hinblick auf das Subjekt die bestmöglichste radiographische Qualität garantieren, werden an Hand von Messdaten und langjähriger praktischer Erfahrung besprochen. Schliesslich wird eine Anzahl von Irrtümern, wie man sie in der praktischen Arbeit häufig sieht, hervorgehoben.

RÉSUMÉ

Les progrès techniques en matière d'automatisation de la prise des radiographies (raccourcissement des temps de pose, indépendance du système de mesure par rapport au kilovoltage et à l'épaisseur du sujet et modification de la disposition du champ de mesure) permettent maintenant de rationaliser le travail de radiodiagnostic par une standardisation de la technique de prise des radiographies. L'auteur se base sur le résultat de mesures et sur une expérience pratique de nombreuses années pour étudier les mesures nécessaires, qui comprennent le calcul de groupes de 'constantes radiographiques' donnant la meilleure qualité radiographique possible. Il termine en signalant un certain nombre d'erreurs les plus fréquentes dans le travail pratique.

REFERENCES

Bischoff, K.: Der Iontomat, ein neuer Belichtungsautomat für Röntgenaufnahmen. Fortschr. Röntgenstr. 71 (1949), 994.

Chelazzi, M. et Attili, S.: Sur le fonctionnement du 'Phototimer'. J. Radiol. 33 (1952), 155.

Frey, K. W.: Untersuchungen über das Verhalten von Röntgenentwicklern bei verschiedener Temperaturregelung. Röntgenblätter 10 (1957), 276.

Franke, H.: Die historische Entwicklung der automatischen Belichtung von Röntgenaufnahmen. Röntgenblätter 6 (1953), 183.

Gajewski, H.: Belichtungs- und Entwicklungsautomatik im Röntgenbetrieb. Röntgenpraxis 10 (1957), 325.

Harnick, L. W. and McLean, H.: Automatic kilovoltage control in spot filming. J. Canadian Assn. Radiol. 5 (1954), 11.

Herz, R. H.: The spectral quantum- and energy-efficiency of calcium tungstate X-ray intensifying screens. Br. J. Appl. Phys. 7 (1956), 182.

Hills, T. H.: An automatic control for diagnostic X-ray exposures. Brit. J. Radiol. 19 (1946), p. 288.

— The practical value of photoelectric timing in relation to röntgen examination of the chest, p. 598. Acta radiol. (1954) No. 116.

Hodges, P. C.: Photoelectric timing in general radiography, p. 605. Acta radiol. (1954) Suppl. No. 116.

— The present status of photo-timing. Amer. J. Roentgenol. 77 (1957), 1.

Lohmann, Th. und Rubens, H.: Ein photoelektrischer Belichtungsautomat für universelle Anwendung. Röntgenblätter 11 (1958), 49.

Lusted, L. B. and Miller, E. R.: An electronic position timer for the fluoroscope. Radiology 67 (1956), 259.

Meiler, J.: Schaltanordnung zum genauen Schalten von im voraus bestimmbaren Elektrizitätsmengen für elektrische Apparate mit Abschaltverzögerung. DRP No. 722, 867 by Siemens-Reiniger-Werke, 1940.

Morgan, R. H.: A photoelectric timing mechanism for the automatic control of roentgenographic exposures. Amer. J. Röntgenol. 48 (1942), 228.

Schott, O.: Untersuchungen über Unterbelastung der Röhre bei Belichtungsautomatik. Unpublished.

Spiegler, G.: Physikalische Grundlagen der Röntgendiagnostik. Thieme, Stuttgart 1957.

Stanford, R. W. and Hills, T. H.: An advance in X-ray film processing. Brit. J. Radiol. 29 (1956), 286.

Stieve, F. E.: Untersuchungen über das Wirkungsprinzip von Belichtungsautomaten für Röntgenaufnahmen. Fortschr. Röntgenstr. 85 (1956), 491.

— Belichtungsautomaten in der Praxis. Röntgenblätter 9 (1956), 325.

— Über die Dominante im Röntgenbild. Fortschr. Röntgenstr. 87 (1957), 80.

— Untersuchungen über das Zustandekommen der Überstrahlung in den randnahen Abschnitten von Röntgenaufnahmen. Fortschr. Röntgenstr. 90 (1959), 126.

Widenmann, L.: Untersuchungen über die Abhängigkeit der Filmschwärzung mit handelsüblichen Verstärkerfolien von der Strahlenqualität. Fortschr. Röntgenstr. 87 (1957), 386.

— Welche Voraussetzungen erfordert das Arbeiten mit universell verwendbaren Belichtungsautomaten. Röntgenblätter 12 (1959), 68.

Vogl, M. und Zeidler, H.: Bildabdeckung zur Beschränkung des Strahleneinfallsfeldes bei Objekten mit gekrümmten Begrenzungsflächen. Röntgenpraxis 11 (1958), 161.

Zieler, E.: Der Amplimat, ein Belichtungsautomat für allgemeine Röntgenographie. Fortschr. Röntgenstr. 86 (1957), 382.
— Untersuchungen zur Belichtungsautomatik unter besonderer Berücksichtigung des Amplimat. Fortschr. Röntgenstr. 88 (1958), 718.
Zimmermann, H.: Zur Aufnahmetechnik der Trachea im Seitenbild. Röntgenblätter 12 (1959), 119.

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POTASSIUM IODIDE SCREENS AND HIGH CAPACITY ROENTGEN TUBES IN ANGIOCARDIOGRAPHY

by

Erik Carlsson

Short exposure times are necessary in angiocardiography to avoid motion unsharpness in the image of the rapidly moving mixture of blood and contrast medium and the pulsatile motion of the cardiac chambers. Short exposure times are also necessary because of the relatively large number of roentgen exposures per unit time that are required in rapid serial film changers. To compensate for the limited mAs factors permissible with roentgen tubes of conventional capacity, relatively high energy (up to 140 kV at 350 mA, KJELLBERG et coll. 1956) have been used to permit reduction in exposure time and to meet the density requirements of large parts as encountered in older children and adults. High energy radiation has the disadvantages of increased scattered radiation to the patient and decreased absorption by iodinated contrast media (TER-POGOSSIAN 1956). Highly concentrated iodinated compounds are known to result in an increased incidence of reactions in angiocardiographic examinations. It is therefore desirable to find ways to reduce the exposure time without increasing the energy level of radiation required for the examination. We have used thallium activated potassium iodine intensifying

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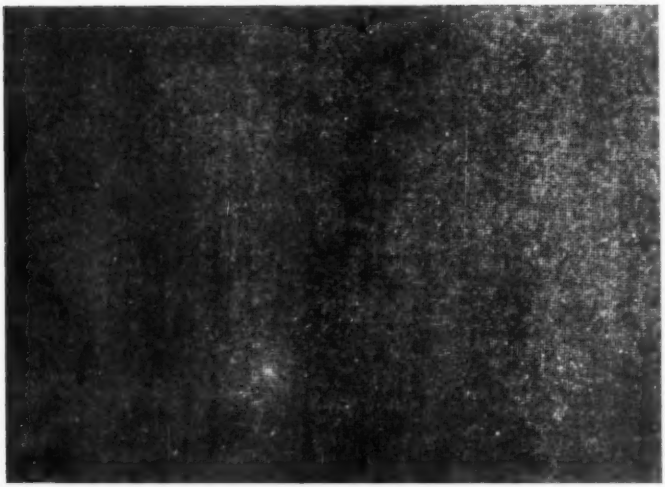

Fig. 1. Film exposed in a Schönander biplane film changer with crisscross grid and potassium iodide screen. The mottling effect, depending upon uneven distribution of the phosphor substance in the screen, is apparent.

screens as developed by the Mallinckrodt Chemical Works and made available to us for experimental trials. These screens were developed as a result of work by TER-POGOSSIAN who suggested the use of alkali halides as phosphor material. They have been used with high capacity roentgen tubes operated at 1 200 mA with relatively large focal spots (2.3 mm²).

The intensifying screens have a resolving power approximately equal to that of conventional high speed calcium tungstate screens. Resolution measured with a Buckbee Mears reticle is 11 lines per millimeter. The speed of the intensifying screens is approximately five times that of par speed screens. The coating consisting of plastic matrix containing finely ground thallium activated potassium iodine crystals, after months of daily use, has shown a loss of approximately 20 % of their original speed, which may result in part from the humid atmosphere in which they have been used. The plastic cover has shown little evidence of abrasion after more than 60 examinations, consisting of 30 films per examination.

Although the particle size, distribution, and thickness of the phosphor layer is essentially the same as in conventional tungstate screens some clumping of the potassium iodide salt results in a mottled appearance in the processed film (Fig. 1). It is expected that a refined commercial product will show improvement in this respect.

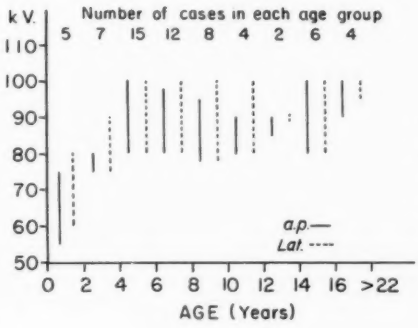

Fig. 2. Diagram showing the variations in energy of the radiation, necessary for adequate exposure in different age groups in angiocardiography with potassium iodide screens, exposure time 0.005 sec and 1 200 mA. The variations depend mostly upon variations in the size of the heart and the patient, but also upon decreasing sensitivity of the screens during the time the examinations have been performed. Focal spot/film distance was in both projections 36 inches (about 90 cm). Royal Kodak Blue film.

In order to investigate the characteristics of the films made with relatively low energy, 63 patients varying in age between 4 weeks and 42 years have been submitted to angiocardiographic procedures using a biplane Schönander film changer. Exposure time in all cases was 0.005 sec at 1 200 mA. The focal film distance was 36 inches (about 90 cm). Kodak Royal Blue Film was used. The energy level of radiation was varied according to the thickness of the examined part. Energy variations required in different age groups are tabulated in Fig. 2. With the above exposure factors, the resulting contrast in the films obtained is high. In cases in which the photographic density of the heart chambers is adequate, the pulmonary vessels are overexposed in the antero-posterior projection in 75 % of the examinations. These exposure factors are at or below the lower limit permissible for satisfactory exposures without compensatory filters. The gain in speed with the potassium iodide screen as compared with that of tungstate crystal screens results from the absorption of twice as much roentgen energy and twice as efficient conversion of energy into useable light (TER-POGOSSIAN 1956).

The geometrical unsharpness due to the large focal spot is permissible for this type of examination as illustrated in Fig. 3.

The radiation dose administered to the patient at 85 kV is 6 mr per mAs for each plane. This value was measured in free air at the skin without back scatter.

The amount of scattered radiation is decreased when the energy of radiation is reduced. This is important in biplane angiocardiography when the films for the two projections are very close to each other and scattered radiation from one results in fogging of the film with simultaneous exposure.

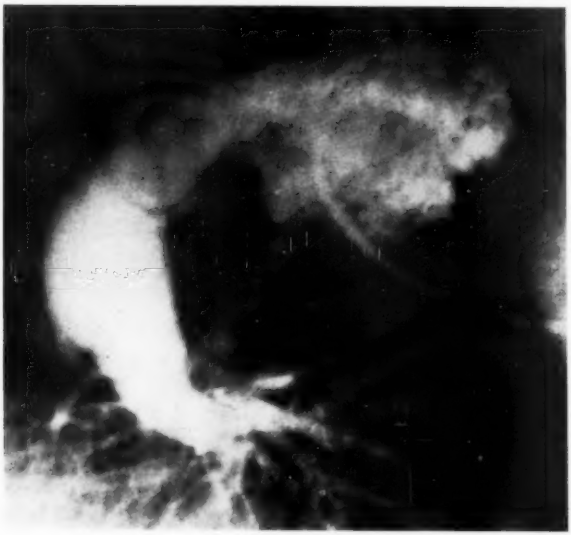

Fig. 3. Angiocardiography in a 7-year-old girl with valvular, pulmonary stenosis, after injection of 32 ml Hypaque 50 %. The demonstration of anatomical detail is adequate. Focal spot size was 2.3 mm² and potassium iodide screens were used. 1 200 mA and 82 kV, 0.005 sec.

Hypaque of 50 % concentration has been used as a standard contrast medium in doses of 1 to 1.3 ml per kg bodyweight, even in cases requiring injections of the right heart for demonstration of left cardiac chambers. Only in patients with large cardiac volumes and/or large shunts was it necessary to resort to higher concentrations of contrast media.

Although the amount of radiation absorbed by the patient using low energy roentgen is proportionally greater than where high energy rays are used, the overall absorbed energy is small due to the use of potassium iodide screens.

SUMMARY

Thallium activated potassium iodide intensifying screens in combination with high capacity roentgen tubes permit the optimal energy level for angiocardiographic examinations. They have permitted reductions in the concentration of iodinated contrast media required for satisfactory density, thereby decreasing reaction risks and the dose of radiation. These advantages are to some extent reduced by the drawback of mottling of the films as obtained with experimental screens and by the geometrical unsharpness caused by the large focal spot of high capacity roentgen tubes.

ZUSAMMENFASSUNG

Verwendung von mit Thallium aktivierten Kaliumjodid-Verstärkungsfolien kombiniert mit Hochleistungsröntgenröhren, ergab bei angiocardiographischen Untersuchungen das beste Resultat. Sie gestattet eine Reduzierung der Kontrastmittelkonzentration und damit eine Verminderung des Injektionsrisikos wie auch der Strahlendosis. Diese Vorteile sind bis zu einem gewissen Grad eingeschränkt durch das Auftreten von Grobkörnigkeit auf den Filmen durch die Verwendung der experimentellen Verstärkungsfolien bedingt, sowie durch geometrische Unschärfe infolge des grossen Fokus der Hochleistungsröhren.

RÉSUMÉ

L'emploi d'écrans renforçateurs à l'iodure de potassium activé par le thallium et de tubes roentgen de grande capacité a permis de choisir le niveau d'énergie le plus favorable pour les examens angiocardiographiques. Ceci a permis de réduire la concentration des moyens de contraste iodés nécessaire pour obtenir une densité satisfaisante; les risques de réaction et la dose de radiation sont ainsi diminuées. Ces avantages sont en partie perdus en raison de l'aspect pommelé des films obtenus avec des écrans expérimentaux et en raison du flou géométrique dû aux grandes dimensions du foyer des tubes à grande capacité.

REFERENCES

Kjellberg, S. R., Mannheimer, E., Rudhe, U., and Jonsson, B.: Diagnosis of congenital heart disease. The Year Book Publishers, Chicago 1959.

Ter-Pogossian, M.: Monochromatic roentgen ray in contrast media roentgenography. Acta radiol. 45 (1956), 313.

— Iodinated x-ray intensifying screens (1956). Unpublished.

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PHYSICAL ASPECTS OF COBALT 60 TELETHERAPY USING WEDGE FILTERS

II. Dosimetric considerations

by

M. Cohen, J. E. Burns and *R. Sear*

The object of using wedge fields in radiotherapy is to irradiate a volume of tissue, situated near to one side of the body, to a high and uniform extent, consistent with the delivery of a minimum dose to underlying healthy tissue. This object may be achieved by using a pair of wedge fields as in Fig. 1 — A. This arrangement results in a region of uniform dose which we refer to as the plateau, indicated by the broken circle (though it is not usually circular in shape), below which the dose decreases very rapidly.

When wedges are used in deep roentgen therapy there is an important complicating factor: to either side of the plateau the dose builds up to a maximum adjacent to the thin edge of each wedge. Since these regions of high dose correspond spatially with the skin of the patient, they provide the effective limit to the type of field arrangements which may be used. Indeed, in order to reduce the 'hot-spot factor' (i. e. the ratio, maximum skin dose/mean tumour dose) to the acceptable clinical limit 1.3 to 1.4, it is necessary in many cases to introduce a third, non-wedge, field as shown in Fig. 1 — A. This field irradiates the tumour area but contributes very little radiation to the regions of high skin dose. A

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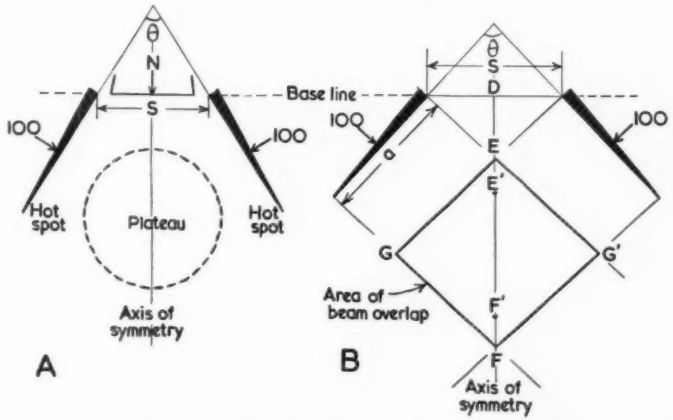


Fig. 1. Basic arrangement of combined wedge fields. A — for deep roentgen-rays, including a third (non-wedge) field, B — for Co^{60} γ-rays.

graphical analysis of the system has been described by COHEN (1959), from which practical dosage tables have been produced.

When the analytical framework just mentioned, which was originally developed for wedge therapy using 250 kV roentgen-rays, is applied to wedge fields used with cobalt γ-rays, it is found that certain simplifications may be made. In the first place, as shown in part I (COHEN, BURNS & SEAR 1960) when the harder radiation is used the hot-spot doses for individual wedge fields are lower and the percentage depth doses higher. The resulting hot-spot factors in a 2-field arrangement are usually well within the stated clinical limit even without the addition of a non-wedge field. It must also be borne in mind that the hot-spot dose in any case occurs a few millimetres below the actual surface. Secondly, the amount of scattered radiation outside the geometrical limits of the beam is comparatively small with cobalt γ-rays, and the wedge isodose lines are straight and almost parallel over a considerable range. As a result, the area of uniformity in a two-field array corresponds closely in many cases to the geometrical area of overlap shown in Fig. 1 — B. Furthermore, the field addition lends itself to mathematical treatment, thereby reducing very considerably the total effort which a full graphical analysis would require. A mathematical analysis has been developed by SEAR (1959), the results of which are in good agreement with those obtained graphically. SEAR's method has been used to calculate the dosage tables, to be described below, currently in use at the London Hospital for cobalt wedge therapy.

Dosage tables for cobalt wedge therapy. For purposes of the mathematical analysis SEAR (1959) showed that the isodose curves of cobalt wedge fields could be regarded as straight lines between beam limits drawn parallel to the central axis, the isodoses bending away rapidly outside these limits. This simplification is illustrated in Fig. 2. Applying the simplified isodose pattern to the case of a pair of cobalt wedges, the geometrical area of overlap is given by EFGG′ in Fig. 1 — B.

It is furthermore assumed throughout that, in contrast to the situation at 250 kV (Fig. 1 — A), no additional non-wedge field is needed with cobalt wedges.

The independent variables of the system (Fig. 1 — B) are the angle θ between the two wedges, their separation s, the field width a, the field length, and an angle Φ called the 'wedge angle', defined by SEAR as the mean slope of the wedge isodose curves within the area of field overlap. This definition, while useful for purposes of mathematical analysis, suffers from the disadvantage that Φ varies to some extent according to the two-field array under consideration. An alternative definition, under which Φ is fixed for each wedge, is as follows (see Fig. 2): Φ is the slope of the isodose line at a depth on the central axis equal to the field width, where 'slope' is defined as the complement of the angle between the isodose line and the central axis. Over the limited range of arrays covered by the dosage tables at present available the variation in Φ (SEAR's definition) is small, and its average value for each wedge equals that given by the second definition to a close approximation.

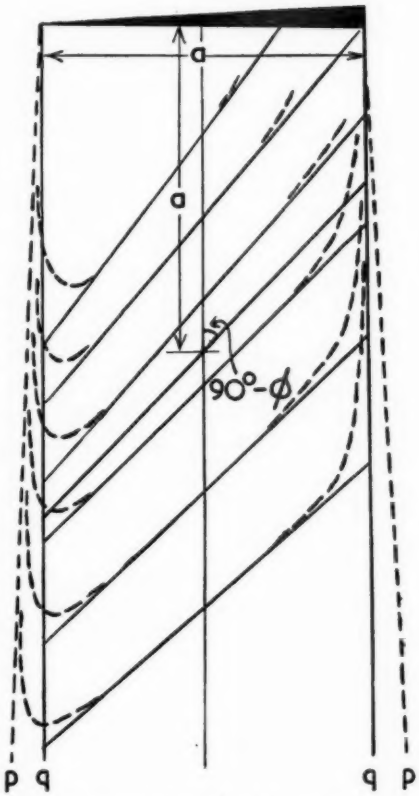


Fig. 2. Representation of cobalt wedge isodose curves for purposes of mathematical analysis. Broken lines: actual isodose curves with divergent beam limits p, p. Full lines: simplified isodose curves with parallel beam limits q,q. Φ = 'wedge angle'.

Table 1

Field width (a)	Wedge angle (Φ)	θ_1	θ_2
4 cm	48°	111°	75°
5 cm	52°	114°	91°
6 cm	40°	94°	63°
8 cm	48°	104°	86°
10 cm	49°	104°	91°

The dependent variables of the system are the size, shape and position of the area of uniform dose (the plateau), the mean percentage tumour dose within this area, and the hot-spot factor.

A slight extension of the definition of COHEN (1959) has been adopted whereby the plateau is said to include all points at which the dose-rate is 0.9 or more of the maximum occurring along the axis of symmetry. SEAR (1959) has shown that for each wedge a pair of angles θ_1 and θ_2 may be defined such that, if $\theta_1 > \theta > \theta_2$, the plateau corresponds closely to the geometrical area of field overlap EFGG′. This is a desirable state of affairs, since not only are the boundaries of the plateau sharply defined but outside this region the dose falls rapidly on all sides. The values of θ_1 and θ_2 are listed in Table 1, although they must be regarded as subject to an error of approximately $\pm 3°$. The apparent lack of smoothness in the variation of θ_1 and θ_2 with field width is due to their dependence on Φ, which is different for each wedge. When θ lies outside these limits, the position of the plateau boundary moves either from E to E′ or from F to F′, according to whether θ is low or high respectively, and furthermore the boundary becomes somewhat indeterminate owing to a low gradient of dose-rate in the region concerned. In general, the arrangements of greatest clinical interest are those within (or only slightly outside) the limits θ_1 and θ_2, for which the plateau is defined by the parallelogram EFGG′.

The mathematical treatment has been used to calculate dosage tables for each wedge, two examples being given in Tables 2 and 3, for the 4 cm and 8 cm wedge respectively. Each table embraces 25 combinations of θ and s, the value of θ varying from 70° to 110° while that of s ranges from 1 cm to 12 cm, smaller values of s being associated with larger values of θ. The plateau size and position are defined in the table by its maximum width GG′ (Fig. 1 — B), which is sensibly constant for a given value of θ, and by the depth (below the base-line) of the upper and lower plateau limits on the axis of symmetry. When θ lies within the range θ_1, θ_2 so that the plateau corresponds to the area of overlap, the plateau limits are given by DE and DF in Fig. 1 — B. In general, however, these limits are defined by the convention already mentioned, i. e. 0.9 times the maximum

Table 2

Dosage table for 4 cm wedge

θ	s (cm)	Plateau dimensions (cm)		Mean tumour dose (per cent)	
		Max. width	Depth below base line	4 cm field length	16 cm field length
70°	4.0	7.0	1.7— 6.3	160	161
	6.0		2.4— 7.0	145	147
	7.0		2.8— 7.4	138	141
	8.0		3.1— 7.7	132	135
	10.0		3.8— 8.4	120	123
80°	2.0	6.2	1.1— 6.0	167	169
	4.0		2.0— 6.9	151	153
	5.0		2.4— 7.3	144	146
	6.0		2.8— 7.7	136	139
	8.0		3.7— 8.6	123	126
90°	2.0	5.7	1.3— 6.7	158	159
	4.0		2.3— 7.7	141	144
	5.0		2.8— 8.2	133	136
	6.0		3.3— 8.7	126	130
	8.0		4.3— 9.7	113	117
100°	2.0	5.2	1.5— 7.4	151	153
	4.0		2.7— 8.6	133	136
	5.0		3.3— 9.2	125	129
	6.0		3.9— 9.8	118	122
	8.0		5.1—11.0	104	109
110°	1.0	4.6	1.0— 7.0	159	161
	2.0		1.7— 7.7	148	151
	3.0		2.4— 8.4	138	141
	4.0		3.2— 9.2	129	132
	5.0		3.9— 9.9	121	124
Hot spot (per cent)				117	117

dose on the axis of symmetry. The divergence of the plateau from the area of overlap is implied in the tables by the specification of the plateau limit concerned to the nearest centimetre instead of to 0.1 cm. In the latter case the accuracy is considered to be $\pm$ 0.3 cm.

The mean percentage tumour dose is given for both the minimum field length (4 cm) and the maximum (16 cm for the two wedges cited), and since the difference between these percentage values is not large, linear interpolation may be used for intermediate field lengths.

Finally, the value of the hot-spot is given: this is independent of θ and s (except for very small values of these parameters), and for the

Table 3

Dosage table for 8 cm wedge

θ	s (cm)	Plateau dimension (cm)		Mean tumour dose (per cent)	
		Max. width	Depth below base line	4 cm field length	16 cm field length
70°	4.0	14	5 —11.2	158	161
	6.0		6 —11.9	144	149
	8.0		7 —12.6	132	137
	10.0		8 —13.3	121	126
	12.0		8 —14.0	110	116
80°	2.0	13	3 —11.2	158	161
	4.0		4 —12.1	144	148
	6.0		5 —12.9	131	136
	8.0		5 —13.8	119	125
	10.0		6 —14.6	108	114
90°	2.0	12	1.7—11.9	143	147
	4.0		2.7—12.9	129	134
	6.0		3.7—13.9	116	122
	8.0		4.7—14.9	105	111
	10.0		5.7—15.9	94	101
100°	2.0	11	1.9—12.6	132	137
	4.0		3.1—13.8	118	124
	6.0		4.3—15.0	105	112
	8.0		5.5—16.2	94	101
	10.0		6.7—17.4	84	91
110°	1.0	10	1.4—10	139	144
	3.0		2.8—11	123	128
	4.0		3.6—12	115	121
	5.0		4.3—13	108	114
	7.0		5.7—14	95	102
Hot spot (per cent)				139	135

majority of arrangements listed is of the same magnitude as, or even less than, the mean percentage tumour dose, so that the question of a clinical limit to the hot-spot factor does not arise. For this reason it is unnecessary to list the hot-spot factor for each array in the table.

Combined field isodose charts. The dosage tables are used in conjunction with isodose charts of two-field treatment arrays. Although 25 arrangements of θ and s are listed in each wedge table, it was considered that the limited utility of providing an isodose chart for each array would not warrant the enormous labour required to produce them. Indeed,

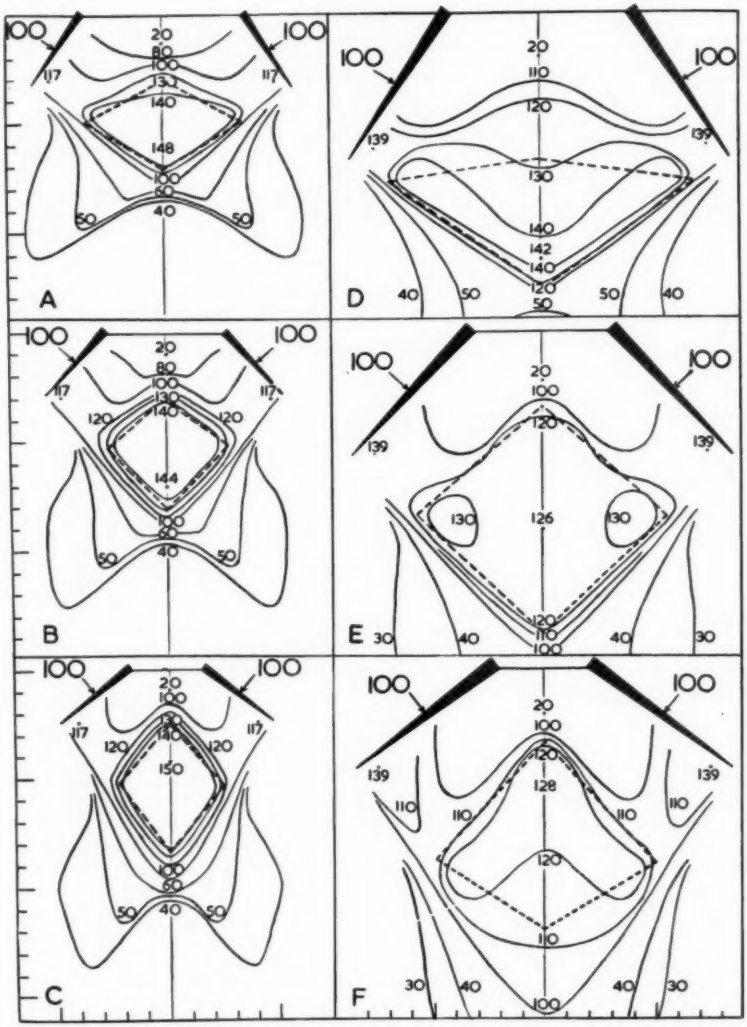


Fig. 3. Isodose charts of combined wedge fields. The broken lines indicate the extent of the plateau as defined in the text.

A, B, and C = 4 cm wedge × 6 cm, and θ = respectively 70°, 90°, and 110°, and s = respectively 7, 5, and 3 cm.

D, E, and F = 8 cm wedge × 6 cm, and θ = respectively 70°, 90°, and 110°, and s = respectively 8, 6, and 4 cm.

it has been found that 3 charts suffice for each wedge, provided that they are carefully chosen to illustrate the salient features of the arrays listed in the table. Accordingly, the 3 charts were drawn for $\theta = 70°$, $90°$ and $110°$, the separation s in each case being the middle value of those given in the table for the value of θ concerned. The isodose charts for the 4 and 8 cm wedges are illustrated in Fig. 3. For each wedge the $\theta = 90°$ chart is the basic arrangement, against which the others should be viewed. The extent of the plateau is shown by a broken line joining the points G and G′ and the upper and lower limits on the axis of symmetry as defined by the convention already mentioned. Interpolation between the $90°$ chart and those for $70°$ and $110°$ is facilitated firstly by the actual numerical information given in the appropriate table and secondly by a general knowledge of the effect on the plateau position and size of variations in θ and s (see below).

An important difference between a small (4 cm) wedge and a large (8 cm) wedge is brought out by the $70°$ and $110°$ charts in Fig. 3. The range θ_1 to θ_2 decreases as the wedge size increases. Thus for practical purposes the whole of the range $70°$ to $110°$ lies within the limits θ_1 and θ_2 in the case of the 4 cm wedge (i. e. the plateau always corresponds to the area of overlap), but this is not so in the case of the 8 cm wedge. The area of overlap itself is approximately square in shape at $90°$, but is elongated at angles greater than $90°$ and flattened at angles less than $90°$, relative to the base-line. The charts show that the plateau area closely follows this variation in shape for the 4 cm wedge, but diverges from it at both $70°$ and $110°$ in the case of the 8 cm wedge for the reason stated above.

The effect of variations in the parameters. Provided that the limits $\theta_1 > \theta > \theta_2$ are not exceeded, the effects of changing θ, s, a or Φ separately, (the other 3 being constant) may be summarized as follows:

1. *The angle* θ. This controls the *shape* and (together with s) the *position* of the plateau. As θ increases, the height EF of the plateau increases while the width GG′ decreases, i. e. the plateau becomes elongated, the ratio EF/GG′ being given by $\tan \theta/2$. The position of the plateau within the array also changes, its depth DE below the base-line being proportional to $\tan \theta/2$. The mean percentage tumour dose decreases fairly rapidly with increasing θ.

2. *The separation* s. This is the variable mainly responsible for the position of the plateau. The size and shape of the plateau are independent of s, but its depth DE below the base-line varies linearly with s. The mean percentage tumour dose decreases fairly rapidly with increasing separation.

3. *The field width a.* This controls the area (and hence the volume) of the region of uniformity. Both the height and the width of the plateau are directly proportional to a, but its depth DE is independent of a. As already noted, however, the range of θ falling within the limits $\theta_1 > \theta > \theta_2$ is inversely proportional to a, so that the larger the wedge the more restricted becomes the choice of θ if the advantages of a sharply defined plateau are to be retained.

4. *The wedge angle* Φ. It is important to consider the effect of variations in this parameter in order to determine whether it is advantageous to produce two or more wedge filters of different slopes for each size. The main function of Φ is to determine the values of θ_1 and θ_2 for each wedge. If a tumour area of known size and location is considered, SEAR (1959) has shown that it is possible to determine unique values of θ, s and a such that the area of field overlap coincides with the required area of treatment. In general, however, the further desirable condition that the plateau coincides with the area of overlap will not be satisfied, because the required value of θ will be outside the limits θ_1, θ_2 for the wedge concerned. This will be the case particularly if the tumour area is markedly elongated, since such areas require the use of either small or large values of θ ($EF/GG' = \tan \theta/2$).

In wedge therapy with 250 kV roentgen-rays the useful ranges of θ and s are limited both by considerations of 'hot-spot' factor and by the practical necessity of setting-up the fields on a wax jig moulded on the patient. Using cobalt γ-rays, however, these considerations may to a great extent be disregarded and the possibility exists of a much wider choice in θ and s than has hitherto been the case. Even to cover the range 70° to 110° of the present dosage tables would require two different 8 cm wedges, with different wedge angles, if coincidence of the plateau and area of overlap is to be obtained throughout the range (i. e. $\theta_1 > \theta > \theta_2$ throughout). On the other hand a single 4 cm wedge, of wedge angle about 45°, is sufficient for the same range. If, however, the working range of θ is to be extended above 110° and below 70°, wedges offering a choice in wedge angle would be needed even for the smallest field width. Whether or not the advantage of such a choice would justify the additional complication involved is being investigated.

The use of a wax compensating wedge

In wedge therapy with 250 kV roentgen-rays, a wax filling is placed in the gap between the surface of the patient and the line representing the applicator faces of the three fields Fig. 4 (a). The wax is moulded to

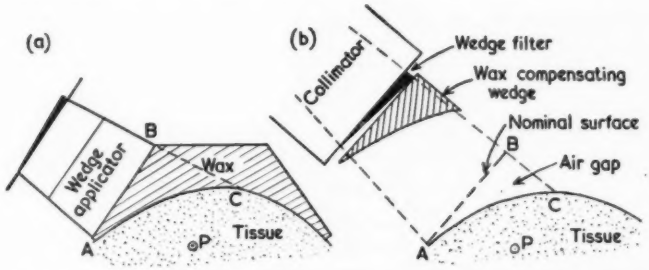


Fig. 4. Method of setting-up a wedge field where the surface of the patient is inclined to the beam axis. (a) Deep roentgen-rays, using a wax jig; (b) Co^{60} γ-rays, using a wax compensating wedge.

the individual patient and forms a jig on which the applicators are set up. Although the arrangement with cobalt wedge fields is basically similar, there are two important divergencies which render a somewhat different approach necessary to the problem of setting-up: (1) in general, applicators are not used in cobalt teletherapy, and (2) it is inadvisable to place wax or other material on the patient during treatment, as by so doing the desirable build-up characteristics of the radiation (which, as shown in part I, remain largely unaffected by the wedge filter itself) will be destroyed.

The problem, therefore, is to provide a temporary reference surface, AB in Fig. 4 (b), for purposes of setting-up, while allowing no material to remain on the patient during the actual irradiation. This entails, of course, the removal of AB after setting-up the field so that an air gap remains between AB and the surface of the patient. However, it must be remembered that AB represents the flat surface of the water phantom in which were made the measurements of dose distribution on which the treatment is based. It is necessary to reconcile this fact with the existence of an air gap. Apart from the possibility of making no correction at all, which may lead to serious error in the estimation of the tumour dose (see below), there are three possible solutions:

I. A correction may be applied on the basis of measurements in a phantom set at an angle to the field.

II. A series of wedge filters may be designed, and appropriate measurements made, for angles 10°, 20°, 30° etc between AB and the patient. In effect, the necessary correction is incorporated within the wedge filter itself. This method has been used by Professor JOHNS (personal communication, 1957).

III. An additional wedge filter may be added to the main wedge so as to compensate for the effect of the air gap in the individual case.

The last solution was considered to be the most elegant in that it allows the same basic set of wedge filters and isodose charts to be used without correction in every case. Furthermore the compensating wedge may be 'tailored' to the requirements of the patient concerned.

Principle of the method. The effect of the triangular shaded volume ABC of unit density material, Fig. 4 (a) on the dose at a point P within the patient is two-fold. In the first place, absorption of primary radiation within ABC decreases the dose at P, relative to that obtaining in the absence of ABC. This decrease is partially offset, however, by the scattered radiation reaching P from ABC. If the volume ABC is transferred to the position shown in Fig. 4 (b), i. e. immediately in front of the wedge filter, the primary beam absorption will be unchanged, but the partial compensation due to scatter no longer occurs. The value of this scatter component depends, of course, on the size of ABC and the position of P. Estimates based on depth dose data for cobalt 60 γ-rays (JOHNS et coll. 1952) indicate that for fields of medium area (50 to 100 cm²) and for points P at medium depths (5 to 15 cm) the scatter contributed to P from the volume ABC (the angle BAC being assumed 30°) is roughly constant at 3 to 6 % of the primary dose at P, i. e. the primary dose and the scatter contributed by ABC fall at approximately the same rate, as the depth of P increases. Thus if the unit density material ABC which is transferred to the front of the wedge filter in Fig. 4 (b) is replaced by a material of density 0.95 g/cm³, the 5 % additional transmission of primary radiation may be expected to compensate, to a first approximation, for the absence of the scatter contribution from ABC.

The bees wax — paraffin wax 1: 1 mixture which is commonly used in radiotherapy for applicator seatings (PATERSON 1948) has a density of about 0.95 g/cm³ and is therefore a suitable material for compensating wedges. The radiological properties of this was mixture (with an addition of 5 % resin flour) have been investigated by OLIVER and KEMP (1949).

Experimental basis. Before checking the above arguments experimentally, it was necessary to ascertain the effect on build-up of a wax block placed between the wedge filter and the patient. Obviously any gross increase in the electron content of the beam would nullify the desirable build-up of ionization beneath the skin and would therefore destroy the basic assumptions of the method.

Build-up curves were measured, as described in part I, with wax sheets (of the composition mentioned) of various thicknesses placed on

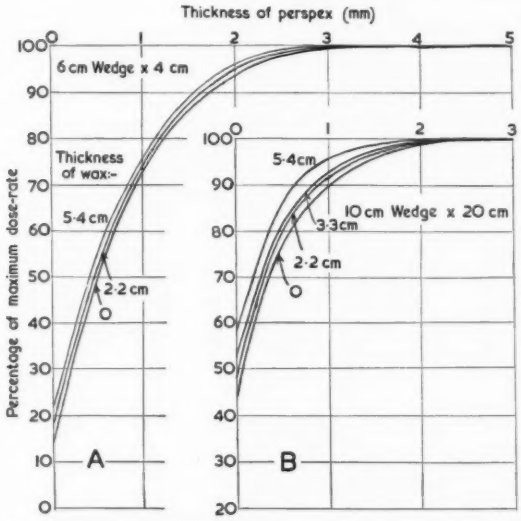


Fig. 5. Build-up curves with rectangular blocks of wax placed in the beam immediately after the wedge filter. A — 6 cm wedge × 4 cm; B — 10 cm wedge × 20 cm.

the wedge filter. By using plates of uniform thickness rather than of wedge section, it was considered that the results would refer to a situation worse than any likely to be encountered in practical therapy. The curves for a small field (6 W × 4) are shown in Fig. 5 — A, and for a large field (10 W × 20) in Fig. 5 — B. It is seen that in the former case the build-up curve is scarcely affected even by a wax block 5.4 cm thick, while in the latter case the same thickness changes the surface dose from 45 % to 59 %, an increase which may be regarded as significant but not disastrous. It was concluded that, in general, wax compensating wedges could safely be employed in the position proposed.

The effect of a wax compensating wedge on the absolute dose-rate and on the shape of isodose curves in a water phantom was investigated by means of the arrangement shown diagrammatically in Fig. 6. The ideal situation, in which the phantom surface is normal to the beam axis, is depicted in Fig. 6 — A. This corresponds, of course, to the arrangement used for all measurements so far described. In Fig. 6 — B the phantom surface is set at 60° to the beam axis, i. e. at 30° to its previous position. This angle was chosen for measurement purposes since it is approximately the largest angle which is encountered in practical therapy and therefore represents the worst situation possible. However, instead

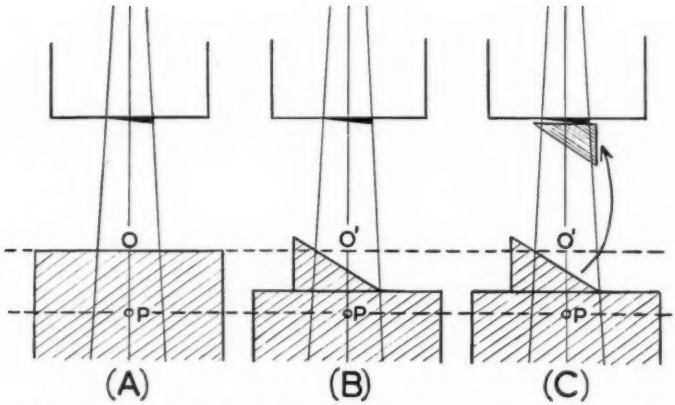


Fig. 6. Experimental arrangements for measurement of dose-rate at a fixed point P. A — Phantom surface normal to beam axis; B — Phantom surface at 60° to beam axis, no compensating device; C — Phantom surface at 60° to beam axis, wax compensating wedge.

of actually turning the whole phantom tank through 30°, it was found to be much more convenient — indeed, essential, for the purpose of accurate transfer from one arrangement to another — to provide in effect a sloping surface to the front of the phantom by means of a separate triangular perspex tank, water filled, which was fixed to the front of the main water tank. A second triangular block, of the same dimensions, was made of wax so that when the two triangles were placed together they formed a new surface through O′ parallel to the old one, on which the field was set-up by means of the usual optical devices. Once the field had been set up, the triangular wax block was removed, thereby reverting to a sloping phantom (Fig. 6 — B). Finally, the wax triangle was placed symmetrically on the wedge filter, the thick end of the wax adjacent to the thick end of the filter, so as to constitute the compensating device which has already been discussed (Fig. 6 — C).

Although, ideally, a comparison of the three arrangements depicted in Fig. 6 — A — B — C, should have involved plotting two additional isodose distributions for each of the 15 combinations of field width and length originally investigated, it was considered that this course would be unjustifiably time consuming. The measurement of isodose curves was therefore confined to selected curves for a small and a large field only (6 W × 4 and 10 W × 20). Some additional isodose curves were plotted, for the compensated system (C) only, for 6 W × 16 and 10 W × 4 fields. These and other fields were also studied by measuring the absolute

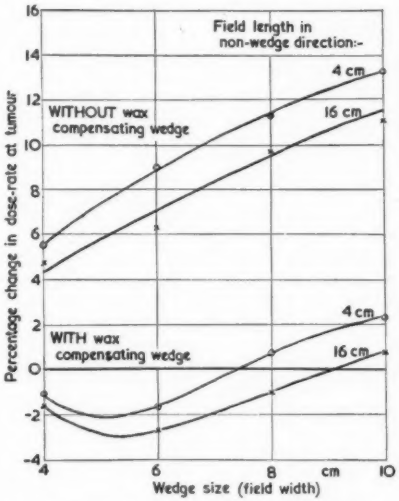


Fig. 7. Percentage increase in dose-rate at the tumour, i. e. the point P in fig. 6, using arrangements (B) and (C), relative to that with arrangement (A).

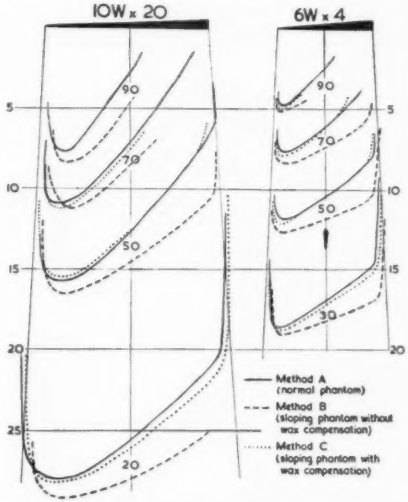

10W x 20
6W x 4
Method A (normal phantom)
Method B (sloping phantom without wax compensation)
Method C (sloping phantom with wax compensation)

Fig. 8. Comparison of isodose curves measured with the three arrangements depicted in fig. 6.

dose-rate at a single axial point in the phantom. Indeed, these measurements were carried out first, since in order to plot and compare isodose curves it was necessary to ensure that the '100 %' levels were the same in all cases (see below).

The choice of a suitable axial point for comparison purposes presented difficulty since the depth at which the tumour dose is administered varies with the wedge and field configuration adopted. The most suitable point (P) was considered to lie on the central axis, at a distance equal to the field width below either O (Fig. 6 — A) or O′ (Fig. 6 — B, and — C).

For each wedge studied the dose-rate at P was measured using both the minimum and maximum field lengths; in the case of the 10 cm wedge some intermediate field lengths were also investigated.

The results of these measurements are shown in Fig. 7, the ordinate being the percentage increase in the dose-rate at P, measured under arrangement (B) or (C) in Fig. 6, relative to the dose-rate at P under arrangement (A). It is seen that, when a sloping phantom is used without a compensating device, the dose-rate at the tumour (considered to coincide with P) is increased by 5 to 13 %, depending on the field dimensions. These experimental values may be compared with the theoretical values for the increase in primary dose. The latter have been calculated from

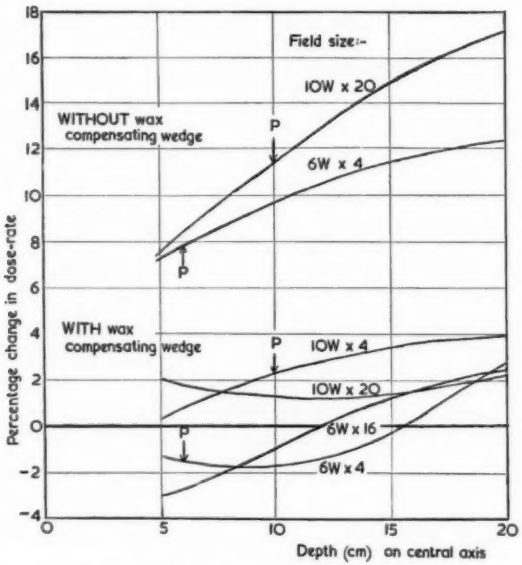


Fig. 9. Percentage increase in dose-rate vs depth on the central axis, for arrangements (B) and (C) in fig. 6, relative to the dose-rate for arrangement (A). The points marked with an arrow correspond to P in fig. 7.

the mass absorption coefficient of cobalt γ-rays in water, i. e. 0.063 cm^2/g (WHITE GRODSTEIN 1957), for known path lengths on the central axis. These calculations indicate increases in dose-rate of 6.8 % for a field width of 4 cm and 16.0 % for a 10 cm field width. The lower experimental values are, of course, attributable to the compensating effect of scattered radiation as already discussed, the compensation being greater for the larger field length.

In contrast to the above figures, Fig. 7 shows that when a wax compensating wedge is used as described, the error in the tumour dose-rate falls within the range $\pm$ 3 %.

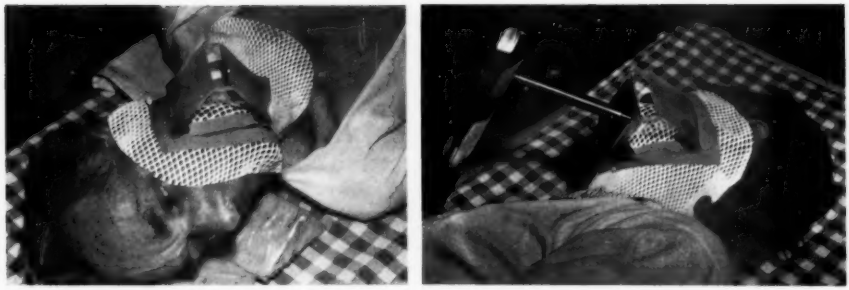
The plotting of isodose curves, for arrangements (B) and (C), was based on the comparison of dose-rates at P illustrated in Fig. 7. This procedure was necessary in order to ensure that the absolute dose-rate at the 100 % point was the same for all arrangements. For example, if the percentage depth dose at P were 70 % in the normal arrangement (A), and the increase in dose-rate at this point in arrangement (B) were 10 %, the new percentage depth dose at P would be 77 %. Fig. 8 shows that the

isodose curves for the uncompensated arrangement are in fact deeper in the phantom and are also of lesser slope. On the other hand, when a compensating wedge is used the isodose curves have essentially the same slope as in the normal arrangement, the residual differences being associated with small differences in axial dose-rate as indicated in Fig. 7.

The isodose curves of Fig. 8 also serve to provide information as to the variation of the error in tumour dose with depth on the central axis, thus supplementing the graphs in Fig. 7 which refer to a single depth only. The curves so obtained, of percentage increase in tumour dose versus depth, are shown in Fig. 9; this also includes the results (with compensating wedge only) for the 6 W × 16 and 10 W × 4 fields. It is seen that, without a compensating wedge, the percentage error increases with depth so that in many cases the error incurred in treatment will be greater than that indicated in Fig. 7 for the single point P. — This effect arises, of course, from the diminishing importance of the scatter contribution from the volume ABC, Fig. 4 (a), so that the error tends to approximate to the value associated with the increase in primary radiation. — When a wax compensating wedge is used the error also tends to increase with depth but the rise is more gradual (there is some evidence of a minimum error at medium depths) and even at 20 cm depth the greatest error appears to be only about 4 %.

Practical details. The composition of the wax used for making the compensating wedges has already been given. A plaster cast is first taken of the region of the patient to be treated. This serves for shaping both the setting-up shell (see below) and the wax compensating wedge. For the latter the wax is softened in hot water and moulded on the cast, finally being cut to shape with the aid of a metal jig, so as to form a wax jig of the same type as that used for setting-up the field in the case of 250 kV roentgen therapy with wedge filters, see Fig. 4 (a). This block is cut in half along the axis of symmetry and each half is trimmed and mounted on a thin sheet of perspex. This is fixed to the main wedge filter by means of two locating pins and holding clips (Fig. 2 in part I). In many cases the two halves of the wax block are sufficiently similar to permit the use of either one for treating both fields, but where the surface contour of the patient in the region concerned is markedly asymmetrical it is necessary to use a separate compensating wedge for each field.

It will be noted that no attempt has been made to scale down the wax compensating wedge to allow for the divergence of the beam. Since the difference between the SSD for which the wedge is fabricated (80 cm) and that at which it is used (64 cm) is comparatively small, it was considered that no great error would be introduced by this cause. In any case the method is based, in the last resort, on the ad hoc results which



a b

c

Fig. 10. Setting-up a wedge field on a patient.

a) Perspex bridge mounted on a shell moulded to the patient.
b) Distance piece used for ensuring correct angulation of the beam.
c) Perspex bridge removed. Wedge filter with wax compensating block in place on collimator.

have already been presented. It may be mentioned, however, that a method of compensation essentially similar has been independently evolved at the Churchill Hospital, Oxford (ELLIS, HALL and OLIVER 1959). In this method compensation is provided by an additional wedge fabricated from small blocks of brass of standard size, the dimensions of the final product taking account both of the density of brass and of the divergence of the beam. This scheme was developed for a cobalt unit in which the wedge filter is placed at 40 cm, the source-skin-distance being 60 cm, so that the effect of beam divergence is greater than in the Picker unit for which the present wedges were produced.

Setting-up procedure. Details of the procedure vary according to the site of the lesion, but the following description is typical. An accurately fitting shell is made using either plaster or a plastic material such as 'Exbex'. The central portion (covering the skin area through which radiation is to pass) is removed, and lugs are fitted so that a perspex bridge of the required dimensions can be mounted on the shell, Fig. 10 (a).

Before setting-up on the patient the collimator is turned so that the open end of the wedge filter slide is upwards, so that subsequent removal of the distance-piece (see below) and insertion of the wedge filter are not impeded by the patient or the couch.

Setting-up is carried out by means of a distance-piece comprising a small plate at the end of a telescopic arm, the whole being mounted on a base-plate which fits into the wedge-filter slide. The distance-plate is accurately perpendicular to the beam axis and is brought into contact with the surface of the perspex bridge Fig. 10 (b). This is the means whereby correct angulation of the beam is ensured. The telescopic arm enables the distance-piece to be removed from the wedge slide without disturbing the set-up in any way. Final centering of the field, and orientation about the central axis, is carried out by means of the optical field simulator provided in the Picker unit. For this purpose the surface of the perspex bridge is rendered opaque by rubbing with sand paper and diagonal lines are ruled. The optical simulating device also serves as a check that the collimator has been set to the correct dimensions, since, as mentioned in part I, no mechanical interlock is provided for this purpose.

Finally, the perspex bridge is removed and the wedge filter, with the appropriate wax compensating wedge attached, inserted in the filter slide, Fig. 10 (c). It was stated in part I that the wedge filter is mounted on its base-plate so that the thick side of the wedge corresponds to the open end of the filter slide. The latter, as just mentioned, is always set upwards, i. e. away from the surface of the patient. Thus the wedge filter is correctly orientated with respect to the patient (Figs 1 and 4) without further rotation of the collimator.

The shell, with its open section corresponding to the entrance port, remains in position during the irradiation and helps to immobilize the patient. In some sites (e. g. abdomen) where such additional support is unnecessary, the perspex bridge is fixed to the shell, which is not provided with a 'window', and they are removed together before the irradiation.

"Exbex" is supplied by the Expanded Metal Co. Ltd., Burwood House, Caxton Street, London, S. W. 1.

Acknowledgements

It is a pleasure to acknowledge the encouragement and valued advice of Dr. L. A. W. Kemp, Dr. W. Shanks and Dr. J. A. Orr.

SUMMARY

The addition of 2 wedge fields for cobalt 60 γ rays is discussed in detail, using the analytical approach of COHEN (1959) and SEAR (1959). Examples of combined field isodose charts are given, and dosage tables permit a choice of 25 two-field arrangements for each wedge. A wax compensating wedge, individually moulded for each patient, allows for the fact that the body surface is usually neither flat nor normal to the beam. The principle and experimental basis of the method are described.

ZUSAMMENFASSUNG

Die Addition von 2 Keilfiltern für Kobalt 60-Strahlung unter Verwendung der analytischen Methode von COHEN (1959) und SEAR (1959) wird eingehend besprochen. Beispiele von kombinierten Feld-Isodosen Tabellen werden gegeben. Die Dosierungstabellen gestatten eine Auswahl von 25 Zwei-Feldanwendungen für jeden Keil. Ein kompensatorischer Wachskeil, der individuell jedem Patienten angepasst ist, trägt der Tatsache Rechnung, dass die Körperoberfläche weder flach noch senkrecht zur Strahlung ist. Das Prinzip sowie die experimentellen Grundlagen der Methode werden beschrieben.

RÉSUMÉ

Les auteurs étudient en détail l'addition de deux champs avec coin pour les rayions γ du cobalt 60, par la méthode analytique de COHEN (1959) et SEAR (1959). Ils donnent des exemples de tables d'isodoses pour champs associés; des tables de dosage permettent un choix de 25 combinaisons de deux champs pour chaque coin. Un coin compensateur en cire, moulé individuellement pour chaque malade, remédie au fait que la surface du corps n'est habituellement ni plane ni normale au faisceau. Les auteurs décrivent le principe et les bases expérimentales de cette méthode.

REFERENCES

COHEN, M.: Physical aspects of roentgen therapy using wedge filters. II. Analysis of wedge field dosimetry. Acta radiol. 52 (1959), 158.

— BURNS, J. E. and SEAR, R.: Physical aspects of cobalt-60 teletherapy using wedge filters. I. Physical investigations. Acta Radiol. 53 (1960), 401.

ELLIS, F., HALL, E. J. and OLIVER, R.: A compensator for variations in tissue thickness for high energy beams. Brit. J. Radiol. 32 (1959), 421.

JOHNS, H. E., EPP, E. R., CORMACK, D. V. and FEDORUK, S. O.: Depth dose data and diaphragm design for the Saskatchewan 1,000 curie cobalt unit. Brit. J. Radiol. 25 (1952), 302.

OLIVER, R. and KEMP, L. A. W.: An investigation into some factors affecting X-ray dose distribution and its measurement. Brit. J. Radiol. 22 (1949), 33.

PATERSON, R.: The treatment of malignant disease by radium and X-rays, p. 161. Arnold, London 1948.

SEAR, R.: A theoretical approach to the radiation dose-rate distribution from combined X- or γ-ray beams, with special reference to wedge filtered beams. Phys. Med. Biol. 4 (1959), 10.

WHITE GRODSTEIN, G.: X-ray attenuation coefficients from 10 KeV to 100 MeV. N. B. S. Circular 583 (1957).

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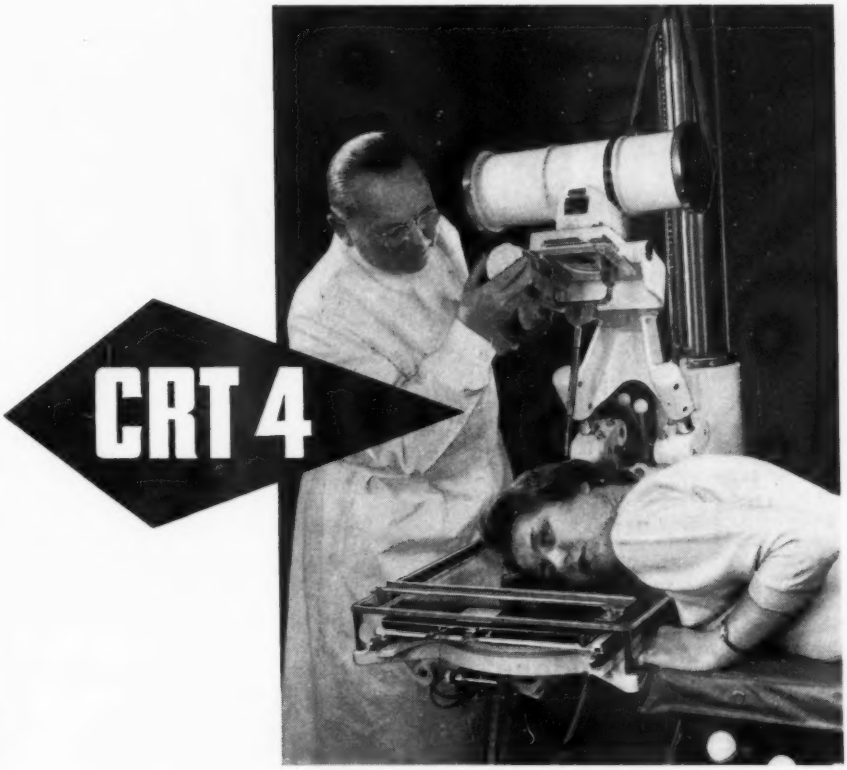

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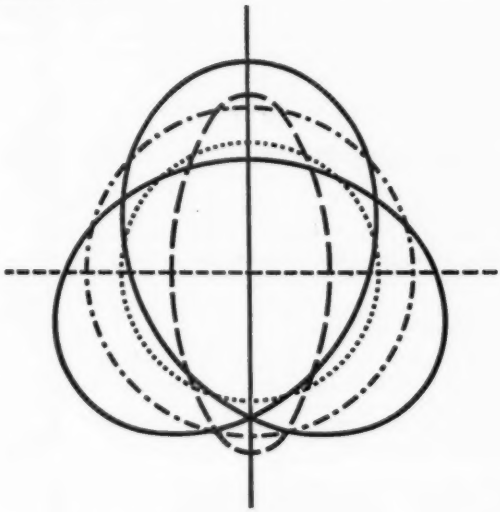

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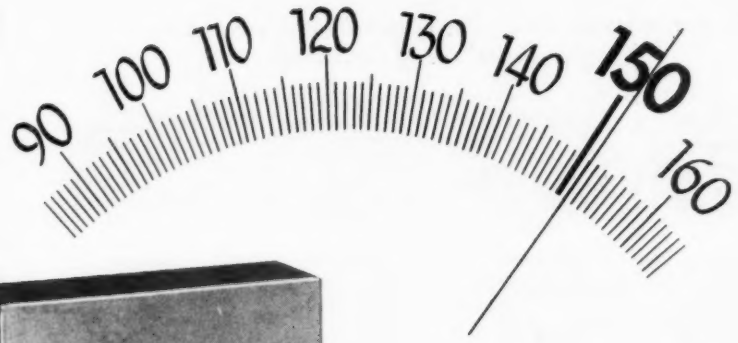

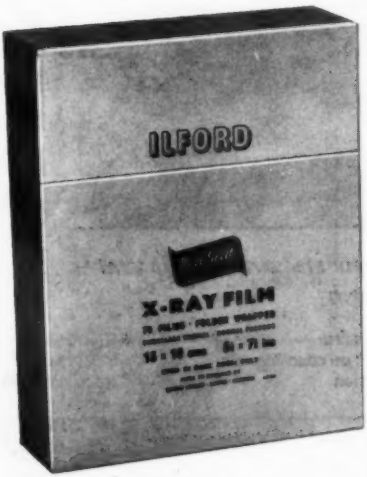

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REFERENCES:

E. Gunnarson: Acta Radiologica 1959, 52, p. 289.
G.-F. Saltzman: Acta Radiologica 1959, 52, p. 282.
P. Virtama: Acta Radiologica 1959, 52, p. 308.

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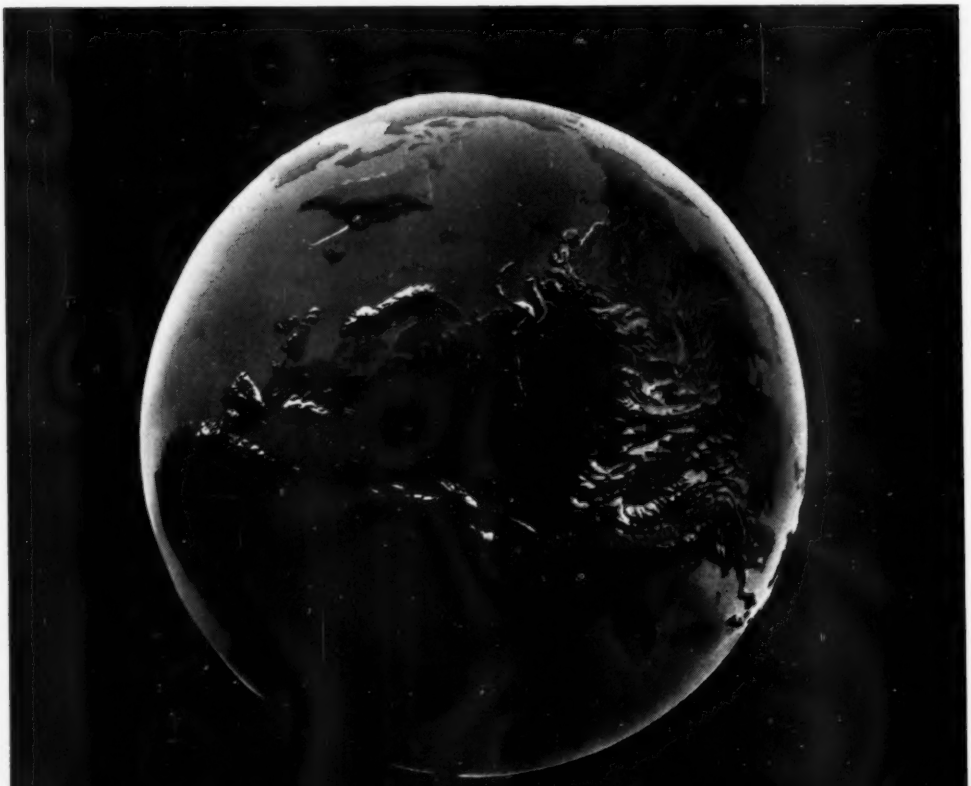

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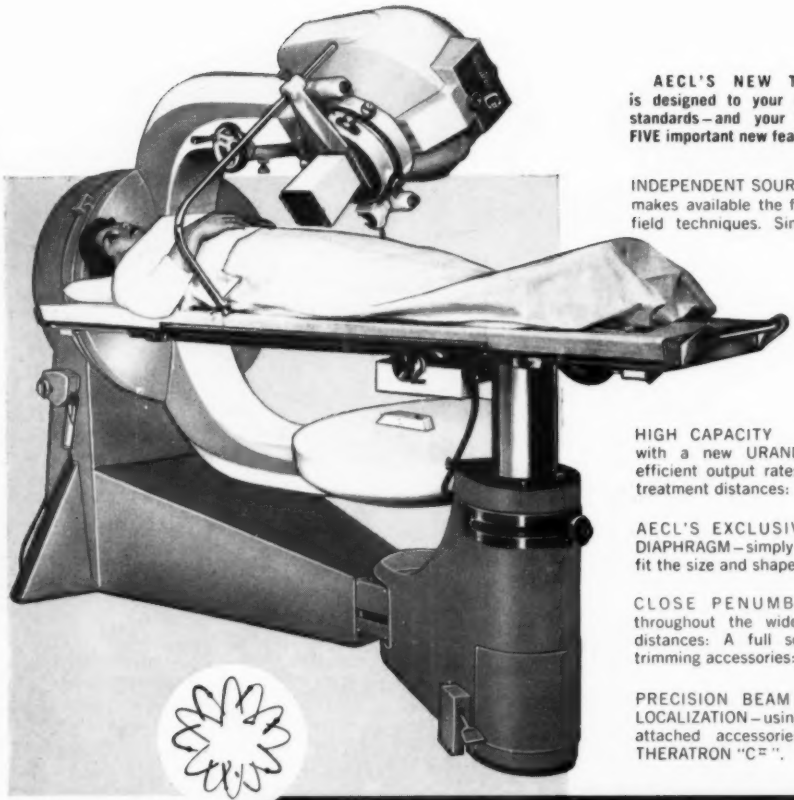

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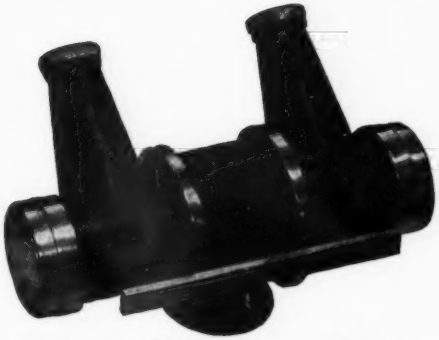

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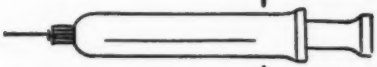

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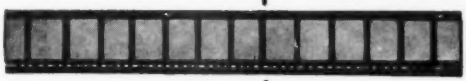

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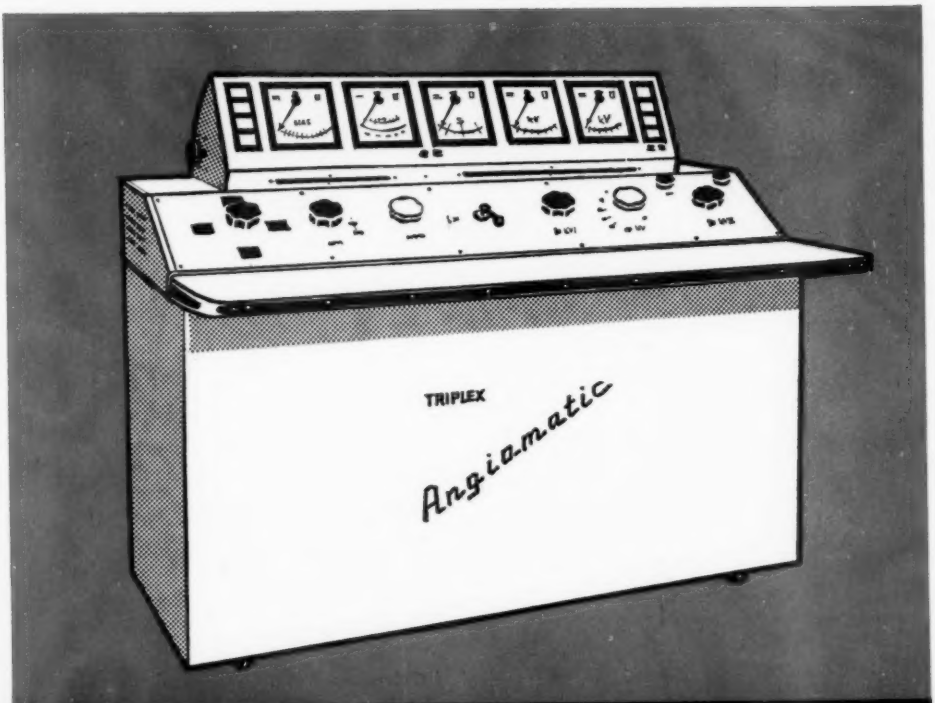

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